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ABSTRACT

This course of study is designed to lead the student to full qualification as an Air Force imagery production specialist. The complete course consists of six volumes: general subjects in imagery production (39 hours), photographic fundamentals (57 hours), continuous imagery production (54 hours), chemical analysis and process control (volumes A and B: 39 and 27 hours), sensitometric control for black-and-white and color processes (39 hours), and statistical quality control methods (36 hours). Each volume provides both theoretical and factual information, exercises, and answers to exercises. Other contents may include a bibliography and appended materials. A volume review exercise (multiple-choice questions) accompanies each of the six volumes. (YLB)

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IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

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COURSE NUMBER	COURSE TITLE	EFFECTIVE DATE
23350	IMAGERY PRODUCTION SPECIALIST (AFSC 23350)	19 May 86

INSTRUCTIONS: The following materials are needed to complete this course. Check this list immediately upon receiving your course package, and if any materials are missing or incorrect (numbers don't match), notify ECI immediately. Use the ECI Form 17 for this purpose, and be sure to include your identification number, address, course and volume number, and VRE form designation (if a VRE is involved). Send all correspondence separately from your answer sheet.[1]

ITEM	TYPE	DESIGNATION OR TITLE	INVENTORY CONTROL NUMBER	VRE ANSWER SHEET IDENTIFICATION
3	VOL	VOL 1, General Subjects for Imagery Production Specialists	23350 01 8603	
4	VRE	VOLUME REVIEW EXERCISE (VOL 1)	23350 01 23	23350 01 23
5	VOL	VOL 2, Photographic Fundamentals	23350 02 8508	
6	VRE	VOLUME REVIEW EXERCISE (VOL 2)	23350 02 23	23350 02 23
7	VOL	VOL 3, Continuous Imagery Production	23350 03 8510	
8	VRE	VOLUME REVIEW EXERCISE (VOL 3)	23350 03 23	23350 03 23
9	VOL	VOL 4A, Chemical Analysis and Process Control	23350 04A 8601	
10	VRE	VOLUME REVIEW EXERCISE (VOL 4A)	23350 04A 01	23350 04A 01
11	VOL	VOL 4B, Chemical Analysis and Process Control	23350 04B 8601	
12	VRE	VOLUME REVIEW EXERCISE (VOL 4B)	23350 04B 01	23350 04B 01
13	VOL	VOL 5, Sensitometric Control for Black-and-White and Color Process	23350 05 8602	
14	VRE	VOLUME REVIEW EXERCISE (VOL 5)	23350 05 01	23350 05 01
15	VOL	VOL 6, Statistical Quality Control Methods	23350 06 8601	
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LIST OF CHANGES

COURSE NUMBER 23350	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO, ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
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NOTE: PLEASE MAKE THE CORRECTIONS INDICATED BELOW. THESE CORRECTIONS MAY OMIT SOME ERRORS SUCH AS TYPOS, THAT DO NOT AFFECT THE MEANING OF THE MATERIAL.

1. CHANGE FOR THE TEXT: VOLUME 1

Page 19, col 2, line 15: Change "The 0-1-0" to "TO 0-1-01."

23350 01 8603

CDC 23350

IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

Volume 1

General Subjects for Imagery Production Specialist

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Preface

WITH THIS VOLUME, you begin a course of study that will lead you to full qualification as an Air Force Imagery Production Specialist (AFSC 23350). The complete course consists of 6 volumes: Volume 1, *General Subjects in Imagery Production*; Volume 2, *Photographic Fundamentals*; Volume 3, *Continuous Imagery Production*; Volume 4, *Chemical and Sensitometric Control*; Volume 5, *Statistical Control and Quality Assurance*; and Volume 6, *Equipment Certification, Testing, and Evaluation*.

Although you may be studying duties and tasks that you are not actually working on, the intent of the CDC is that you become a fully qualified Imagery Production Specialist. Since this CDC is the primary source of testable information for your specialty knowledge test (SKT) at promotion time, you must study it with two purposes in mind: (1) you must study it to become a fully knowledgeable specialist; and (2) you must study it to increase your change for promotion.

In Chapter 1 of this volume, you will learn about career ladder progression and the duties and responsibilities of the 5-level specialist. Chapter 2 covers the specific operational security (OPSEC) vulnerabilities of AFSC 233X0.

Chapter 3 discusses the Air Force Occupational Safety and Health (AFOSH) Program. This chapter is extremely important to you, since it covers your physical well-being. We will cover electrical hazards, chemical safety, and compressed gases. We will also discuss the establishing and evaluating of safety programs.

Chapter 4 deals with technical order publications and is basically a review of information you learned in the basic resident course. It covers the use of indexes, technical manuals, and research of commercial publications.

Chapter 5, Supervision and Training, covers the Air Force Graduate Evaluation Program, environmental protection, equipment and laboratory cleanliness and preventive maintenance procedures.

Chapter 6 covers the mathematics most used in imagery production.

In Chapter 7, we discuss photo procession interpretation facilities, and in Chapter 8 (the last chapter), we will discuss the application of computers in today's aerial reconnaissance.

A bibliography is included at the end of this volume.

Code numbers appearing on figures are for preparing agency identification only.

The inclusion of names of any specific commercial product, commodity, or service in this publication is for information purposes only and does not imply indorsement by the Air Force.

To get an *immediate response* to your questions concerning subject matter in this course, call the author at AV 926–4142 between 0800 and 1600 (MT), Monday through Friday. Otherwise, write the author at 3420th Technical Training Group/TIMZS, Lowry AFB CO 80230–5000, to point out technical errors you find in the text, Volume Review Exercises, or Course Examination. Sending subject matter questions to ECI slows response time.

NOTE: Do not use the Suggestion Program to submit changes to this course.

Consult your education officer, training officer, or NCO if you have questions on course enrollment or administration, Your Key to a Successful Course, and irregularities (possible scoring errors, printing errors, etc.) on the Volume Review Exercises and Course Examination. Send questions these people can't answer to ECI, Gunter AFS AL 36118–5643, on ECI Form 17, Student Request for Assistance.

This volume is valued at 39 hours (13 points).

Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes the examinee should check the Index of ECI Study Reference Material to determine the correct references to study.

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NOTE: This course teaches through numbered lesson segments, each containing a behavioral objective, text, and exercise. The objective sets your learning goal. The text gives you the information you need to reach that goal, and the exercises let you check your achievement. When you complete each segment, see whether your answers match those in the back of the volume. If your response to an exercise is incorrect, review the objective and its text.

Career Ladder Progression

CONGRATULATIONS! You have successfully completed the basic technical school course and have been awarded an Air Force specialty code (AFSC 23330), Imagery Production Specialist, apprentice level. Your enrollment in this CDC starts the next phase of your Air Force career. When you complete this phase, you are eligible to be awarded AFSC 23350.

In this chapter, you will study several factors that affect your progression in the audiovisual career field. As you begin your study of this CDC, keep in mind the following quote from AFR 35-1, *Military Personnel Classification Policy (Officers, Warrant Officers, Airmen)*:

> An individual's career progression, including promotion in the Air Force, is directly related to the efforts expended by the officer or airman to attain and maintain qualification in his or her specialty. Therefore, attaining and maintaining this qualification are primarily the responsibility of the individual. Facilities for self-improvement such as off-duty education, ECI courses, technical training, career development courses, and self-study guides are available, or can be made available, to all individuals. Each officer and airman is encouraged to use every opportunity for increasing his or her technical qualifications and enhancing his or her professional and military knowledge.

In view of the preceding information, you see that the accomplishment of this CDC is one of your responsibilities toward your career progression. As you study this chapter, you will learn the other responsibilities.

1-1. Progression in Career Ladder 233X0

The Audiovisual Career Field includes many different areas of photography. You are in the 233X0, Imagery Production area. Let's look at your career field and see what upgrade requirements you must meet to progress.

001. Select mandatory upgrade requirements from a requirements list, and name additional unlisted mandatory requirements for the award of AFSC 23350.

Upgrade Requirements. Changes or awards of an AFSC are based on standards from AFR 39-1, *Airman Classification*, and information from AFR 35-1. These standards are prescribed in paragraph 3 (Specialty Qualifications) of each specialty description. There are mandatory and desirable requirements in "*knowledge*," "*education*," "*experience*," "*training*," *and* "*other*." Mandatory requirements are minimum for the award of an AFSC. Desirable requirements aid in your ability to work in your AFSC. The extract below was taken from the specialty description. It shows both the mandatory and desirable requirements for the award of the 5 level in your AFSC.

SPECIALTY QUALIFICATIONS

a. Knowledge:

(1) Knowledge of the imagery production process including camera operation; imaging systems; characteristics of sensitized materials and chemistry; the imagery processing and reproduction cycle; color timing; color correction; care, storage, and evaluation of sensitized materials is mandatory. Basic knowledge of mathematics; statistics; sensitometry, densitometry; exposure and processing effects; imagery evaluation; and typical mobile processing facilities is mandatory. Possession of mandatory knowledge will be determined according to AFR 35-1.

(2) Knowledge of operator repair/preventive maintenance procedures; theory and use of optical effects printers; aerial sensors; motion picture; microphotography theory and equipment; and video film transfer is desirable.

b. Education: Completion of high school is mandatory. Courses in photography, chemistry, computer science, and mathematics are desirable.

c. Experience: Experience in functions such as operating imagery production equipment, process control, and image evaluation is mandatory.

d. Training:

(1) Completion of a basic imagery processing course is mandatory for award of the semiskilled AFSC.

(2) Completion of a 5-level CDC is mandatory for the award of the skilled AFSC.

e. Other:

(1) Minimum of Grade 1 color vision as defined in AFM 160-17 is mandatory.

(2) A Top Secret security clearance is mandatory for award and retention of the semiskilled/skilled AFSC.

(3) Minimum ASVAB scores of General 65 and Mechanical 40 are mandatory. Waiver of these scores are prohibited.

The mandatory requirements of item 3e were met before you were assigned to the Imagery Production Career Field.

Other mandatory requirements for the award of an AFSC are set forth in AFR 35-1. This regulation shows that to be awarded a 5-level AFSC, you must have:

(1) Satisfactory performed in the 5-level AFSC for 6 months.

(2) Successfully completed all training requirements (this CDC is one of them).

(3) Been recommended for upgrading by your supervisor.

(4) Met other mandatory requirements or equivalents.

Exercises (001):

1. If you have a 3-level AFSC, have met the mandatory 5-level knowledge requirements, and have been recommended for upgrading by your supervisor, what other requirement must you meet before you can be awarded the 5-level AFSC?

2. From the following list of upgrade requirements, select those that are mandatory:

   a. Knowledge of the imagery production process.
   b. Knowledge of video film transfer.
   c. Knowledge of optical effects printers.
   d. Completion of high school.
   e. Experience in operating imagery production equipment.
   f. Completion of a basic course.

3. According to AFR 35–1, this CDC is part of which one of the mandatory requirements for the award of AFSC 23350?

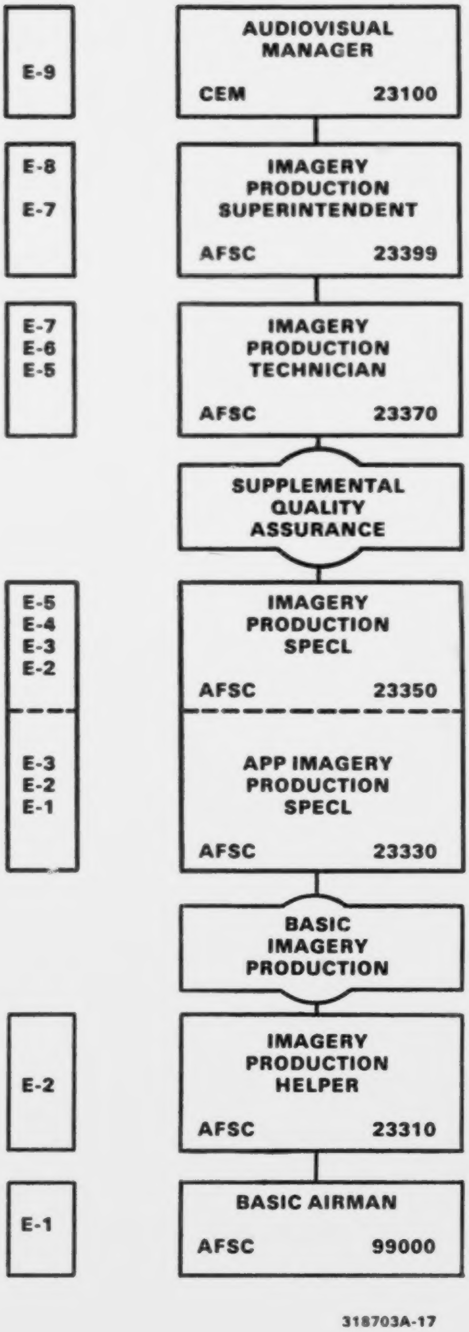
E-9
AUDIOVISUAL MANAGER
CEM 23100
E-8
E-7
IMAGERY PRODUCTION SUPERINTENDENT
AFSC 23399
E-7
E-6
E-5
IMAGERY PRODUCTION TECHNICIAN
AFSC 23370
SUPPLEMENTAL QUALITY ASSURANCE
E-5
E-4
E-3
E-2
IMAGERY PRODUCTION SPECL
AFSC 23350
E-3
E-2
E-1
APP IMAGERY PRODUCTION SPECL
AFSC 23330
BASIC IMAGERY PRODUCTION
E-2
IMAGERY PRODUCTION HELPER
AFSC 23310
E-1
BASIC AIRMAN
AFSC 99000
318703A-17

Figure 1–1. 233X0 career ladder.

002. Relate the specialty levels in career ladder 233X0 to their corresponding pay grade criteria.

Grade Spread. Air Force specialties normally include a job progression ladder because of the difficulty in learning all of the duties of the job. You will be permitted to climb that ladder one step at a time. Your Air Force specialty also covers more than one pay grade, so you will progress in pay as your skill on the job increases.

Considering the many uses of imagery production, you can see why you must achieve a high degree of skill and versatility in your job. The audiovisual career field and imagery production career ladder are designed to help you advance your skill level.

Looking at figure 1-1, you can trace your progress up the imagery production ladder and relate each skill level to one or more pay grades.

The pay grade you are now holding should be E–3 which is comparable to airman first class. At the completion of this CDC, along with the recommendation of your supervisor, you will be competing with other airmen for the pay grade of E–4.

The top of the 233X0 career ladder shows that the imagery production superintendent requires a grade-skill relationship of E–8 (senior master sergeant) and the 9-skill level (AFSC 23399) is needed. Chief Enlisted Manager (CEM) codes are used to identify chief master sergeants and selectees as top enlisted managers. Looking again at figure 1-2, you can see that the audiovisual manager requires an E–9 (chief master sergeant) with a CEM code of 23100. A closer look will show also that this "chief" can come from either one of the six career ladders under the audiovisual career field.

Exercises (002):

1. You may have held or may be advancing towards the list of pay grades that follow. Relate the AFSC that is mandatory before you can hold each pay grade.

   a. E–5.

   b. E–9.

   c. E–3.

   d. E–7.

2. List the pay grades that may be held by persons with the 3-, 5-, 7-, and 9-level AFSCs.

1-2. Duties of the 5-Level AFSC

In your case, you were awarded the 3-level AFSC upon graduation from the basic imagery production course. As soon as you reached your first duty station and were promoted to E–3, you were placed on upgrade training to the 5-level AFSC. Now, although you hold a 3-level AFSC, you are performing the 5-level duties. Later on in your career, you will perform duties as a 7-level and hopefully make it to the 9-level. Now, let's see what your duties are and how they compare with the 7- and 9-level duties.

003. Given a list of the duties performed at the 3, 5, and 7 skill levels, identify the level at which each is most apt to be performed.

Duties and Responsibilities. The duties and responsibilities for the 5-level imagery production specialist are given in paragraph 2 of the specialty description. This paragraph is quoted as follows:

DUTIES AND RESPONSIBILITIES

a. Operates black-and-white and color (manual, semiautomatic and automatic) imagery processing equipment. Processes reversal, original negative, master positive, duplicate negative, duplicate positive, and release prints. Preinspects exposed materials for physical defects. Assembles and processes film and paper materials. Sets, monitors, and adjusts immersion, spray, and viscous type processors to ensure proper solution application, agitation, replenishment, air flow, water flow rates, constant solution temperatures and dryer temperature and humidity. Monitors photographic materials through continuous processors to assure proper tracking, speed and tension. Loads and downloads materials in continuous processors without interrupting processing. Detects and corrects machine or tracking malfunctions in total darkness or proper safelight through sense of sight, hearing, or touch. Processes film and paper in tray and dip tank using time-temperature control techniques. Uses non-conventional processing systems.

b. Operates manual, semiautomatic, and automatic imagery duplication equipment. Operates contact, projection, optical, and non-conventional printers to produce a variety of aerial, motion picture sound tracks, and visual end products in total darkness or under proper safelight conditions. Operates printers to obtain proper image size, sharpness, geometric distortion correction or rectification, color balance, density, contrast, and color saturation in accordance with printing instructions.

c. Edits, titles, and assembles imagery materials. Compiles imagery (original, duplicate, select prints, etc.) in accordance with work requests. Edits material, attaches leaders, includes annotations when required, and titles film with required information.

d. Establishes and maintains standards, guidelines, and practices. Processes sensitometric strips. Adjusts solutions and regulates equipment operation in conformance with established standards and quality assurance guidelines. Mixes and uses processing solutions and cleaners. Operates silver recovery equipment.

e. Controls imagery processing and assures quality by both manual or computerized methods. Measures and analyzes sensitometric and densitometric functions. Constructs, interprets, and analyzes effects of exposure/development on emulsion density and contrast. Computes and correlates film speed, gamma, exposure, and color balance with sensitometric data. Constructs and uses time-gamma, time-temperature, and tone reproduction charts to determine exposure and processing parameters. Uses sensitometric curves to establish and maintain process control.

f. Analyzes chemistry and controls processes. Verifies condition and silver content of photographic solutions. Measures and controls pH, specific gravity, composition, concentration, and silver content. Calculates residual thiosulfate content of processed film and paper. Controls use of processes to include immersion, spray, viscous, non-silver, diffusion transfer, and other non-conventional processes for specialized applications. Operates laboratory equipment such as pH meters, distillery and balances. Establishes replenishers rates.

g. Conducts statistical quality control. Uses statistical quality assurance methods to maintain process control. Determines mean and variance of data groups and process aim points to ensure imagery processing conforms to accepted standards. Uses control charts to maintain process tolerances. Uses acceptance sampling methods to maintain quality assurance.

h. Maintains quality assurance through evaluation. Evaluates resolution, acuity, graininess, granularity, and dimensional accuracy of photographic images. Determines probable causes of exposure and processing anomalies. Operates image evaluation equipment.

i. Verifies accuracy of metrology equipment, printers, processors, flowrate meters, and mixtanks. Tests and corrects printer illumination for consistency, intensity, and color balance. Assures accuracy of weights and measures, temperature and speed indicators.

j. Supervises imagery production personnel. Assigns and distributes work load among subordinate personnel. Supervises or performs normal operator maintenance and repair of laboratory equipment. Conducts on-the-job training.

If you were to look at paragraph 2 of the 23370 specialty description in AFR 39–1, you would find some of the headings as follows:

a. Operates black-and-white (manual, semiautomatic, and automatic) imagery processing equipment.

b. Operates manual, semiautomatic, and automatic imagery duplication equipment.

c. Supervises editing, titling and assembling of imagery materials.

d. Controls imagery processing and assures quality by both manual or computerized methods.

e. Analyzes chemicals and controls processes.

Notice that although headings *a* and *b* read the same, the material contained under the headings is quite different. The 5 level is responsible for assembling and processing film and paper material, setting and monitoring the

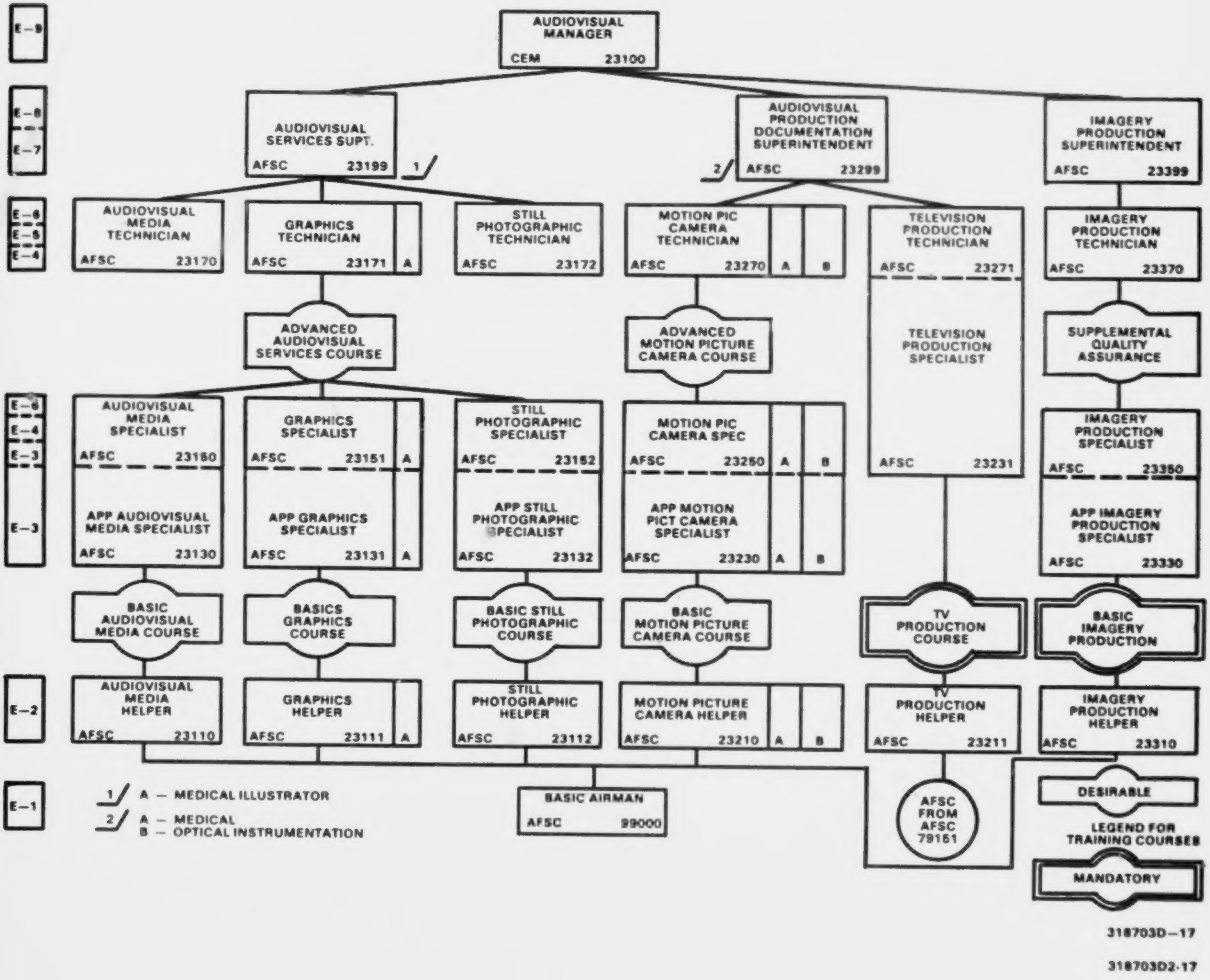
E-9
E-8
E-7
E-6
E-5
E-4
E-5
E-4
E-3
E-3
E-2
E-1
AUDIOVISUAL MANAGER
CEM 23100
AUDIOVISUAL SERVICES SUPT.
AFSC 23199
1/
2/
AUDIOVISUAL PRODUCTION DOCUMENTATION SUPERINTENDENT
AFSC 23299
IMAGERY PRODUCTION SUPERINTENDENT
AFSC 23399
AUDIOVISUAL MEDIA TECHNICIAN
AFSC 23170
GRAPHICS TECHNICIAN
AFSC 23171 A
STILL PHOTOGRAPHIC TECHNICIAN
AFSC 23172
MOTION PIC CAMERA TECHNICIAN
AFSC 23270 A B
TELEVISION PRODUCTION TECHNICIAN
AFSC 23271
IMAGERY PRODUCTION TECHNICIAN
AFSC 23370
ADVANCED AUDIOVISUAL SERVICES COURSE
ADVANCED MOTION PICTURE CAMERA COURSE
TELEVISION PRODUCTION SPECIALIST
AFSC 23231
SUPPLEMENTAL QUALITY ASSURANCE
AUDIOVISUAL MEDIA SPECIALIST
AFSC 23150
GRAPHICS SPECIALIST
AFSC 23151 A
STILL PHOTOGRAPHIC SPECIALIST
AFSC 23152
MOTION PIC CAMERA SPEC
AFSC 23250 A B
IMAGERY PRODUCTION SPECIALIST
AFSC 23350
APP AUDIOVISUAL MEDIA SPECIALIST
AFSC 23130
APP GRAPHICS SPECIALIST
AFSC 23131 A
APP STILL PHOTOGRAPHIC SPECIALIST
AFSC 23132
APP MOTION PICT CAMERA SPECIALIST
AFSC 23230 A B
APP IMAGERY PRODUCTION SPECIALIST
AFSC 23330
BASIC AUDIOVISUAL MEDIA COURSE
BASICS GRAPHICS COURSE
BASIC STILL PHOTOGRAPHIC COURSE
BASIC MOTION PICTURE CAMERA COURSE
TV PRODUCTION COURSE
BASIC IMAGERY PRODUCTION
AUDIOVISUAL MEDIA HELPER
AFSC 23110
GRAPHICS HELPER
AFSC 23111 A
STILL PHOTOGRAPHIC HELPER
AFSC 23112
MOTION PICTURE CAMERA HELPER
AFSC 23210 A B
TV PRODUCTION HELPER
AFSC 23211
IMAGERY PRODUCTION HELPER
AFSC 23310
BASIC AIRMAN
AFSC 99000
AFSC FROM AFSC 79151
1/ A — MEDICAL ILLUSTRATOR
2/ A — MEDICAL
B — OPTICAL INSTRUMENTATION
DESIRABLE
LEGEND FOR TRAINING COURSES
MANDATORY
318703D-17
318703D2-17

Figure 1-2. Airman audiovisual career field chart.

processor, loading and downloading materials and operating printers in accordance with printing instructions. The 7 level, however, is responsible for supervising the processing of film and paper, ensuring that processing parameters are maintained, establishing emergency procedures, evaluating imagery, and ensuring that printers are set for optimum results. Notice, too, that heading *d* is quite different from that in the 5-level description.

Exercises (003):

1. At which skill level are you most likely to be asked to clean a processing machine?

2. At which skill level would you most likely be concerned with planning and scheduling work assignments?

3. At which skill level would you most likely be concerned with preinspecting unprocessed film?

004. Specify duties performed at various skill levels that are associated with supervision.

The 9-level AFSC responsibilities deal with such items as planning and organizing imagery production activities, directing imagery production activities, establishing and conducting OJT programs, inspecting and evaluating imagery production activities, and performing technical imagery production functions.

We have given you a brief outline of the 7-level and 9-level duties so that you can see where you fit into the picture as a 5-level specialist. Complete specialty descriptions for the 7 and 9 levels are in AFR 39–1.

Exercises (004):

1. The following list of duties is associated with the Imagery Production Career Field. Use AFR 39–1 to help you identify those duties associated with supervision.

    a. Select printing.
    b. Supply procurement.
    c. Black and white film processing.
    d. Orientating new personnel to the organization.
    e. Planning laboratory layout.

Security

WITH THE GREAT number of persons in the Air Force, security could become an overwhelming problem unless everyone does his or her job. Many times, the big secret is the one that is kept secret. During World War II, the development of the atomic bomb was a well-kept secret. Very few people even knew of its existence until the first bomb was dropped. On the other hand, many times the enemy has learned of troop movements and equipment capabilities through seemingly innocent talk.

Your job is such that you are exposed to a lot of information that could aid the enemy. Some of this information is obvious: items such as aircraft reconnaissance capabilities, radar, and electronic photoequipment. However, most of us know enough not to discuss these items unless it becomes necessary in the performance of our duty. Many times we like to complain about the problems of our job. A comment such as: "Everytime that a certain thing happens, the radar has to be recalibrated," could give the enemy a tip as to how the enemy might possibly make our radar less effective. Now, let's look at some of the security items we are concerned with.

2-1. Operations Security (OPSEC)

All information about an Air Force operation needs protection because such information is valuable to our enemies. This protection is provided under the Air Force OPSEC program. Operational security is an overall security program relating to mission accomplishment. It is concerned with the information, actions, and activities that are sensitive in the sense that they can telegraph our punch to the enemy—they can give advance warning. The successful completion of our mission and the use of OPSEC is greatly dependent upon each individual's recognizing what information and actions need protection. You should already be familiar with OPSEC from your instruction in basic military training. In this section, we cover specific OPSEC vulnerabilities that are peculiar to the 233X0 career field and how these security procedures can be established and evaluated to cope with these peculiarities.

005. Specify OPSEC vulnerabilities of the 233X0 career field.

Your duties as an imagery production specialist may require you to come into close personal contact with the Air Force's OPSEC program. Operational security can be divided into three major areas and, therefore, three areas of vulnerability. Let's take the three major areas: (1) operations, (2) procedures, and (3) communications, and discuss how some of the same potential weaknesses apply to your job.

Operations Vulnerabilities. These are weaknesses attributed to policies and patterns of accomplishing the mission of an imagery production laboratory. An example of this is placing reconnaissance missions on excessively routine schedules. If a mission started at the same time each day and ended at the same time each day, an enemy agent would have a clue as to how long certain tasks take to accomplish the mission. From this, the enemy could easily determine if the mission being performed was reconnaissance, mapping, strike, etc.

Another operations vulnerability which must not be overlooked is in the area of the working schedule of the processing laboratory. Letting everyone go home when the mission is aborted because of inclement weather or aircraft maintenance can, once again, be a clue to your laboratory's function or the area that your reconnaissance mission is assigned to cover. Coordination with other agencies lacking proper safeguards for classified information is another possible operation vulnerability. There is considerable risk in coordinating with agencies that do not have proper safeguards for classified information. If requested to obtain and present classified materials to a unit taking part in an operation, you may find that the unit does not have proper storage facilities. You should make sure that the classified materials are secure at all times, and you must determine this prior to requesting the classified materials.

Procedural Vulnerability. This potential vulnerability deals with the mechanics of operating a unit, such as posting duty rosters, transportation schedules, or dining hall operations orders in unsecure areas. For example, consider a shipping label attached to a case of 9.5-inch (24.13-cm) aerial duplicating film. From such a label, an agent might determine mission purpose from a code name or contents list, target area from a destination marked on the label, or even when the mission takes place from the due date listed on the label.

The reconnaissance materials that you use in your work will be generated by numerous sensor systems, both classified and unclassified. By the very nature of these materials, you can learn valuable information about the sensor systems, as well as the actual imaged areas. For these reasons, the appropriate security classifications will be formed on the film identification leader, film title blocks, film cans, work orders, and film storage areas. Keep in mind that all reproductions made from classified material is the same classification as the originals; therefore, they must be accounted for, and they are subject to the same safeguards as the original.

It is each individual's responsibility to take precautions to prevent access to classified information by unauthorized persons; and you must always be aware of a project's classification. Classified documents, when removed from storage for working purposes, must be kept under constant surveillance with face down or covered when not in use. Your attitude toward and understanding of these facts will greatly enhance your unit's OPSEC program and will ensure that the necessary precautions are followed to safeguard classified material.

Communication Vulnerabilities. These are too numerous and varied to discuss each of them separately. But for the communications phase, describing a classified product over the telephone violates not only OPSEC principles but communication security (COMSEC) as well. You can see that in order to have an effective OPSEC program, all personnel must take an active interest.

No one intentionally gives away classified information, yet it often happens. A good operational security program will greatly reduce the amount of leaked information.

Exercises (005):

1. Which of the following are OPSEC vulnerabilities of the 233X0 career field?

   a. Using the telephone to describe classified audiovisual equipment.

   b. An increase in the use of certain classified materials.

   c. Requesting classified audiovisual materials for an organization that is without proper storage facilities.

2. Give some examples of procedural vulnerability for an imagery production laboratory.

Photographic Safety

EACH OF US IS responsible for making our job as safe as can be expected. Since as many accidents occur off the job as during normal duty hours, safety is a full-time responsibility. Although accident prevention is a function of management, commanders and staff officers are dependent technically on their first-line supervisors to uncover unsafe practices and conditions. No one is more qualified, or in a better position, to find and correct both routine and unusual safety hazards than the supervisor of an imagery production facility. He is the one man who deals directly with both the worker and the job. He is in the best position to improve the worker's attitude toward his job, to fill gaps in his knowledge of the job, to improve the worker's job proficiency, to insist on safe practices on the job, and to correct unsafe conditions involved in the job. When a supervisor fails in any one of these responsibilities, he can expect inefficiency and costly results.

Now let's consider some accidents and causes which may occur within the area occupied by an image production facility.

3-1. Chemical Safety

Imagery production technicians, in the course of their duties, enter many strange environments. Many technicians follow much the same routine from day to day and need only brief reminders about accident prevention. Others who work with potentially dangerous chemicals must exercise good safety practices continually. Your job falls in this category, since mishandling of certain chemicals can cause serious injury to you.

006. Identify the chemical hazards that image production personnel are exposed to in laboratory operations.

Chemical Safety Hazards. Some of the chemicals used in photography are only skin irritants, but others can cause more serious injuries. All chemicals should be regarded as potential poisons and should be handled with caution. Acids and caustic alkalies are dangerous and can cause severe burns if they come into contact with the skin. Some chemicals generate heat and may start fires when in contact with other materials.

When you mix chemicals, always add the chemical to the water. If water is added to any strong acid, a violent reaction occurs, heat is generated, and the solution boils and sputters. This could earn you an unexpected and painful visit to the local hospital. When water is mixed with a caustic soda, heat is generated and liquid caustic may sputter out of the container. Potassium hydroxide (caustic potash) has the same hazardous reaction as caustic soda.

Sulfuric acid is a strong dehydrating agent. It extracts moisture from most material, including your skin. Heat generated in the process may ignite wood, paper, and similar material under some conditions. Anyone working with, or near, strong acids or caustics should wear protective clothing—such as aprons, rubber gloves, and goggles. Never mix an acid with a cyanide because as they combine, a lethal gas is released, and there is little hope of reviving anyone who has inhaled this gas.

Exercises (006):

1. Identify the situations below that constitute chemical safety hazards.
    a. Adding acid to water.
    b. Spilling concentrated sulfuric acid on a stack of prints.
    c. Handling potassium hydroxide without wearing goggles.
    d. Tasting an unknown chemical.
    e. Smelling the fumes directly from a container of unknown solution.

2. What reactions take place when water is added to a strong concentrated acid?

3. What characteristic makes an acid injurious to personnel?

4. When you mix strong acids or caustic alkalies, what protective clothing should you wear?

5. What safety practices should a supervisor initiate if he wants to minimize the dangers of chemical hazards?

007. Given a situation relating to the handling or mixing of chemicals, determine the necessary precautions.

Chemical Mixing Precautions. As we have mentioned earlier, because many chemicals are toxic or poisonous, they must be handled with extreme care. Some of the precautions you should take when handling or mixing photographic chemicals are discussed below.

(1) Never smell a chemical directly from the bottle. Instead, hold the bottle a little distance from your nose and sniff its odor cautiously rather than inhaling deeply.

(2) Never taste a chemical.

(3) Handle all chemicals cautiously; some can produce burns or skin irritants.

(4) When mixing a strong acid with water, add the acid slowly to the water while stirring continuously; otherwise, the solution may boil violently and splatter on your face and hands, causing serious burns. Remember, never pour water into acid.

(5) Be sure that the chemical mix room or area where you are mixing chemicals is well ventilated. The fumes or dust from some chemicals can be very irritating to your nose and eyes, as well as harmful to photographic sensitized materials.

(6) Store chemicals in airtight containers in a cool, dry place away from photographic sensitized materials. Chemical fumes and vapors may deteriorate paper and film emulsions.

(7) For external contact with acids, caustic, or toxic chemicals, flush the affected parts with copious quantities of water, remove soaked clothing, and seek medical attention immediately.

(8) In any case of ingestion of any type of chemical, seek medical attention immediately. Do not attempt to introduce liquids or to induce vomiting.

Mercuric Compounds. One class of chemical compounds deserves special attention—compounds containing mercury. Even though these chemicals are seldom used in photography, there are occasions when tests for residual thiosulfate necessitate the use of mercuric chloride.

Based on a toxicity scale of one to five, with five being the most toxic, mercuric chloride is rated at five. Seven drops of 5 percent mercuric chloride solution can be lethal to a man weighing 170 pounds if taken orally. If this solution comes into contact with the skin, vomiting will occur within 10 to 15 minutes. Furthermore, death has resulted from external exposure to mercuric chloride.

Chemical Solvents. Of equal concern are chemical solvents. Because of their toxicity, all solvents and their vapors should be regarded as hazardous. Benzol and chloroform are very toxic and must be used with care. When using any type of solvent, make sure that the room has adequate forced ventilation. If the odor of a solvent is present for more than a few minutes, either increase the ventilation until the odor leaves or wear a proper respirator.

In the case of an accident, the person affected should be rushed to the dispensary and be seen by the doctor on duty at once.

Exercising the proper care in mixing chemicals is just as important to you as employing properly the method you use in any other duty. Always keep your chemical mixing room and facilities immaculately clean, neatly arranged, and in good order. Make certain all chemical containers are in good condition, clean, and clearly labeled. Have your chemical mixing room well lighted and ventilated. Finally, be certain that all safety information is displayed prominently.

Exercises (007):

1. What safety gear should be used when mixing concentrated acid?

2. Write out the rule to follow when diluting acids.

3. Explain the dangers when the above rule is violated.

4. What are the dangers when an electric mixer is operated near a flammable solvent?

5. Describe the physical makeup of the chemical mix room when mixing bulk chemicals.

3-2. Electrical Hazards

As a worker in an image production facility, you continuously work with electrical equipment. Some equipment operates on standard 110 VAC, some equipment requires 208–230 VAC, and all are capable of delivering a lethal shock. Furthermore, since much of the equipment contains chemical solutions, the hazard is increased. If a spill or overflow occurs, the danger of electrical shock is even greater.

008. Identify the electrical hazards that personnel are exposed to in an imagery production facility.

Electrical Shock. The wide use of electrical facilities and equipment, such as processing machines and printers that require high voltages for their operation, exposes imagery production personnel to many of the accompanying hazards. Poor judgement in the use of electricity and electrically powered laboratory equipment is a major cause of injuries, electrical shock, and damage to expensive equipment. Ground operations personnel are exposed constantly to the dangers of severe burns and shock resulting from contacting "hot" circuits and to the danger of injuries received from fires caused by improper or careless use of electrical facilities and equipment. Short circuits, overloading, accidental grounding, poor electrical contacts, and misuse are all responsible for major accidents involving electricity.

Environmental conditions (rain, freezing, etc.) influence the deterioration of power cables leading from outside generators to mobile photographic facilities. These cables pose an ever present safety hazard to the personnel that operate these facilities.

As an example of the care that must be taken to overcome electrical safety hazards, inspections are made of wiring in portable laboratories such as may be set up in the field under theater combat conditions. A typical inspection schedule may appear as follows:

Item	*Inspection*	*Period*
Electrical lines	Check for cracks, abrasions, knicks, or cuts.	Every 7 days
Lines, junction boxes, outlets	Check connections for security of attachment, excessive corrosion, or damage that may impair operation or be dangerous to personnel.	Every 7 days
Lines	Check that part numbers on cables are legible or have not been removed.	Every 90 days
Fire extinguishers	Check that seal is not broken.	Every 180 days
	Check that weight is correct	Every 180 days
	Check that pressure is correct.	Every 180 days

Exercises (008):

1. Would an improperly grounded contact printer be an electrical safety hazard? Explain.

2. What is the major cause of injuries when working with electrically powered equipment?

3. How do we combat the deterioration of power cables used with a mobile photographic facility?

009. Given a list of situations related to the handling of electrical equipment, explain the conditions that would present electrical hazards.

Electrical Conditions. Although adequate training in equipment use and operation and adequate instruction in safety requirements will help to reduce accidents caused by electricity, there is still the possibility of human error—that incalculable "something" that makes ground safety programs necessary. Often airmen are so thoroughly familiar with their assigned tasks that they become negligent, and their negligence results in preventable accidents. Unfortunately, electrical hazards are present in nature, too. Summer storms in which rain and lightning are present contain electrical potentials that are capable of causing damage to structures and equipment, as well as death through electrocution. However, experience has shown that, even in such circumstances, there are certain precautions that can be taken to prevent death and damage.

Death or serious injury due to electrical shock are usually caused by heart muscle spasm (ventricular fibrillation) or by paralysis of the breathing nerve center in the brain. The factors that determine the seriousness of an electric shock are (1) voltage of the power source contacted and (2) electrical resistance of the body. Together, these two factors determine the current's strength, its duration, exact path the current will take through the body, and the condition of the body organs in the current path at the time of contact.

An electric current through the body can reduce the rhythmic contractions of heart muscles to spasmodic contraction efforts. If this condition occurs, the heart cannot supply purified blood to the rest of the body, and death may result if the shock victim is not released from the current source within 3 minutes. If the person is released from the current source soon enough, the heart muscles may resume their regular rhythmic contractions normally, or when stimulated by artificial respiration.

Electric shock damage to the nerve center regulating the breathing muscles may cause death by suffocation. Suffocation can also result from current passing through the chest muscles, even though the heart and the breathing nerve center are not damaged or paralyzed. A current of over 15 milliamperes (ma), flowing from one arm to the other, is enough to render the victim incapable of releasing himself from the current source and, at the same time, to paralyze the muscles needed for breathing. A milliampere is one-thousandth of an ampere; an ordinary house current will normally be rated at 10 amperes.

Electric shocks are never without danger. At commercial powerline frequencies, voltages between 200 and 1000 volts are particularly harmful since heart muscle spasm and paralysis of the respiratory center occur in combination. Some of the available photographic processing and printing equipment require (depending upon phase) between 208 and 230 volts to operate effectively. Current flow, in each leg of wiring in a typical processing machine, may run between 50 and 65 amperes. Such legs or lines require 100-amp fuses to take care of line surges or overloads. On the other hand, lower voltages can also prove fatal, as evidenced by records of deaths caused by 32-volt farm light systems. The body response to certain magnitudes of current is as follows: 5 to 15 ma stimulates the muscles, 15 to 19 ma can paralyze the muscles and nerves through which it flows, 25 ma and above may produce permanent damage to nerve tissue and blood vessels, and 70 ma and above may be fatal.

The injurious effects suffered during electrical shock depend upon the path of the current through the body. Generally, the current takes the most direct route through the body from the two points of contact. For this reason, any current path that passes through the heart or the brain is particularly dangerous.

To meet equipment specifications, manufacturers of photographic printers and processors design and construct their equipment to be free of shock hazards inherent in all equipment requiring high voltages. A means of doing this is to incorporate interlocks within the equipment. An interlock is a safety device that automatically opens the alternating current supply circuit when a cover (as in a cabinet) or door providing access to the circuit is opened. In cases requiring that such a door be opened, you should not rely solely on the presence of interlock switches for protection from electrical shock. These safety devices can fail, either through intentional tampering (as present in sabotage) or through mechanical or electrical breakdown.

When personnel are subjected to direct lightning strikes, the results are nearly always fatal. Although extraordinary escapes from direct strikes have been recorded, it is considered extremely unlikely that this was the actual circumstance. The shock from direct strikes is so great that survival is rare. The major portion of lightning casualties arises from secondary conditions, such as side flashes and induced charges. First-aid treatment, especially artificial respiration administered in time, may prevent death from any but direct charges.

Exercises (009):

1. What action should a supervisor take when a new employee is involved in an electrical accident?

2. What action should a supervisor take when a trained technician continues to perform his job in an unsafe manner?

3. A supervisor has observed one of his subordinates performing his duties in a manner that may be detrimental to his safety. Should he correct the subordinate immediately or wait until he sees him in private?

4. What is your first course of action when you see that a technician has been a victim of electrical shock?

5. You have been informed by a subordinate that some electrical gear can cause an electrical shock. What should you do?

3-3. Mechanical Safety

It is true that accidents are preventable. However, many persons—either through ignorance or misunderstanding—unfortunately believe that accidents are the inevitable results of unchangeable circumstances or fate. Not only is this belief false, but it is also illogical; it fails to consider the law of cause and effect, the basic ingredients of all accidents. In other words, accidents do not happen without cause, and the identification, isolation, and control of those causes are the underlying principles of all accident prevention techniques. Even natural elements can be controlled to some extent, and it is only in the realm of nature involving phenomena—such as lightning, storms, or floods—that accidents are extremely difficult to prevent. However, even the effects of these can be minimized, as in the case of securing aircraft when strong winds are expected. These accidents due to nature, estimated at only 2 percent of all accidents, are arbitrarily classified as being "acts of God."

010. Select situations, common to all machine operators, that might lead to safety hazards.

When you operate any piece of Air Force equipment, there are two principal things you learn: *first*, how to operate the equipment properly, and *second*, how to operate it safely. While you may think of these two things as pretty much the same, there is a difference. Of course, if you don't operate equipment properly, you may, at the same time, be operating it unsafely, because improper operation is often the cause of accidents. You can set the controls properly to operate a piece of equipment and yet be careless and get your hand in some gear, with disastrous results. Do your job properly. This way, you will get the job done quickly, accurately, and safely, and you will prevent injury to yourself and to others.

Plan Your Work. The more thoroughly you plan your work, the more likely you are to perform it properly and safely. When you perform a task without first planning for it, you usually make many unnecessary operations, make many mistakes, and use many unsafe motions. Since efficiency and safety are two of your most important considerations as an imagery production technician, it is essential to plan your work thoroughly before you perform it. During this preoperational planning, you organize all operations necessary to complete the work properly, efficiently, and safely.

The most important thing when planning a job is to check all pertinent safety instructions. These concern protective clothing, machine guards, or the type of equipment you are using. Study safety instructions carefully, especially if you're doing a job for the first time. As you begin work each day, even on comparatively simple tasks, plan ahead to be sure all pertinent safety principles are observed. If any protective devices are required, have them available.

Discipline Yourself During Work. You know from basic military training and classroom training how important good discipline is, whether it is in close order drill or in a classroom project. It is even more important when there is a threat to your personal safety. We are not saying that your job is extremely hazardous. It is hazardous only when you don't work safely! This is why you must have discipline.

Just what does good discipline have to do with you and safety on the job? Perhaps we can best illustrate this by an example. Let's say that you are operating a high-speed processor. The local OIs tell you to never remove the side panels unless the machine is turned off. This is to prevent getting hands or loose clothing caught in moving gears. However, you've done the job so many times that you know you can remove the cover without hands or loose clothing getting caught in the gears. So you ignore that caution and leave the machine running while removing the cover. Chances are you may get by with this once or maybe several times. However, you are just possibly betting your arm that you can get by with breaking the law of good discipline. You know better, but since "old sarge" isn't there to enforce the law, you think you can get away with shortening the procedure. You may cheat on safety sometimes but rarely all of the time without getting caught. Remember, once may be too often.

Stay Alert. Another basic principle of safety is alertness. Constant alertness is definitely a prime requisite in avoiding accidents. Fundamentally, alertness means paying attention—not just now and then—but all of the time. Unless you pay close attention to what you're doing at all times, you undoubtedly end up doing something wrong; again, you have a situation in which an accident may happen.

The enemies of alertness are external and internal distractions—things that occur inside of you, either mentally or physically.

Perhaps the most serious disturbances are those that you and your buddies create. It is inexcusable for you or any buddy to do anything that may cause you or someone else to have an accident. External distractions usually take the form of horseplay.

There are quite a few kinds of internal distractions that may destroy alertness. These may be either mental or physical. The number of internal distractions are just too many to cover in detail. However, let's talk about a couple so that we can see the importance of keeping mentally and physically alert while on duty.

Mental distractions most often occur when you are thinking about personal problems rather than concentrating on what you are doing. When your attention is diverted, it is impossible for you to be alert. It is impossible to pay attention to more than one thing at a time, so in the interest of personal safety, you had better forget about personal problems while working. If your personal problems are so great that they interfere with your work, let your supervisor know. He may be able to help you solve them. Don't let your personal problems make you cause an accident that will damage equipment or hurt somebody.

Daydreaming is another common mental distraction. This is a particularly dangerous type. Your mind can become so absorbed in the pleasant thoughts of a daydream that alertness is almost completely destroyed. There are very few of us who haven't, at one time or another, been caught "napping" in a daydream by a sudden emergency that we otherwise would have seen. And it isn't necessary to have an emergency—even during a routine job operation, a daydream may sufficiently destroy alertness to cause an accident.

The other kinds of internal distractions are physical. The most prevalent kinds of physical distractions are fatigue, severe pain, and illness. Most of us take care of severe pain and illness, or at least we should. The problem of fatigue cannot always be eliminated. You should recognize it and not let it go too far before you inform your supervisor.

Exercises (010):

1. Select the following situations that might result in personal injury.

   a. Poor working planning.

   b. Organizing work operations.

   c. Disregarding certain steps in local OIs.

   d. Mentally planning a vacation while operating a continuous processor.

   e. Keeping physically fit.

2. A newly assigned airman in the imagery production facility is mixing solutions which contain ammonia. The airman inhales too many of the fumes and has to leave the room. This situation is probably because of:

   a. Poor planning.

   b. Daydreaming.

3. You open the back of a printer that has an automatic electrical power cutoff to empty the vacuum bag. You assume that because of the automatic electrical power cutoff, you will not get shocked. However, you do get a shock when you accidentally touch an uninsulated wire. What is the probable reason for this accident?

   a. Mental distraction.

   b. Breach of discipline.

011. Given a list of situations relating to accidents, determine their probable causes.

The operating condition of machines and equipment plays a vital role in your safety and the safety of the equipment. If any machine is not in good operating condition, you may lose job efficiency or have a safety hazard. Furthermore, speed controls on electrically operated equipment must be in top condition. A defective speed control may allow the machine to run too fast, thus causing an accident.

In any of the previous situations or in any situation involving the proper operating condition of machines and equipment, the prime responsibility lies with you—the operator. Before operating any machine or piece of equipment, become thoroughly familiar with its various parts and become especially familiar with the safety hazards that may develop due to defective or worn parts. Know what hazards to look for and look for them frequently. A very dangerous condition can develop when you receive a new model or similar equipment or a modified version of current equipment. In either case, never assume that just because you know the proper operating and safety procedures for the old equipment, you know all about the new equipment. Be sure to find out how the new or modified equipment differs from the one you are used to. Carefully read the technical order or accompanying instruction manual. Remember, new models of equipment, although similar, may have different parts, different controls, and different safety hazards.

Exercises (011):

What is the probable cause of the situation listed below?

1. During the day shift, a new piece of equipment was installed; Amn Smith comes to work on swing shift and immediately starts the machine. A half hour later the dry box overheats and quits working.

3-4. Compressed Gases

In many imagery production facilities, compressed gases in the form of nitrogen and air are used daily in normal production. These compressed gases pose a special type of safety hazard in that neither of them is lethal.

012. List the hazards associated with the use of compressed gases.

In some facilities, a nitrogen system of agitation is used. It is one of the ways constant agitation of film during development can be produced. Known as the gaseous burst agitation system, it can be used with many films as well as with some papers. This system uses compressed nitrogen released in bursts at controlled intervals through a series of tiny holes located in a distributor device placed at the bottom of a processing tank. When correctly monitored and first released, the nitrogen gas burst imparts a sharp displacement pulse to the entire processing solution. Then, as the bubbles make their way to the surface of the solution, a localized agitation action takes place around each bubble. By virtue of their great numbers and the random paths they follow to the surface, the nitrogen bubbles provide effective agitation at the surfaces of film or paper suspended in the solution. Cylinders of compressed nitrogen, air, etc., could pose a very serious hazard because of pressure.

Pressure. Pressure systems contain gases or liquid under pressure and sometimes at extreme temperatures. The degree of hazards in pressure systems is proportional to the amount of energy stored, not the amount of pressure present. Therefore, low-pressure high-volume systems can be as hazardous as high-pressure systems. The cylinders must be secured and care must be taken to ensure the cylinders do not get knocked over, possibly breaking the valves, and causing the cylinder to become a lethal projectile. In addition to pressure, nitrogen could also create another problem—that of asphyxiation.

Asphyxiation. Nitrogen gas is odorless, tasteless, colorless, and chemically inert. It is neither corrosive, explosive, nor flammable. By itself, nitrogen will not support combustion, and it is neither toxic nor irritating and will not combine freely with other materials. Only at high temperatures will nitrogen combine with electropositive elements to form nitrides, which are very hard and brittle substances such as magnesium nitride, boron nitride, or trisilicon tetranitride. Gaseous nitrogen is soluable only slightly in water and is stable chemically. Although it rarely happens, nitrogen may dilute the atmosphere within a processing facility to an unsafe level to create the danger of asphyxiation. Dilution of the atmosphere to proportions of one volume of nitrogen to two volumes of air is not dangerous, but equal volumes are hazardous to personnel.

Exercises (012):

1. Name two safety hazards associated with the use of nitrogen compressed gas.

013. Given a situation related to the handling of compressed gases, choose the correct procedures.

As stated before, nitrogen under pressure presents a constant safety hazard because of the very large amounts of energy stored in the compressed gas. Only fittings, hoses, valves, regulators, tanks, and other handling equipment that have been tested for existing pressures may be used.

All pressurized gas systems are installed, tested, inspected, and maintained as specified in appropriate Air Force directives. If a leak is discovered when the cylinder valve is opened, you should close the valve immediately. If the leak continues, take the cylinder outdoors where the remaining gas is expelled into the atmosphere. Take the same steps if a leak develops in the safety device. Always

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close the cylinder valve when nitrogen gas is not being used. Proper use of nitrogen gas calls for opening the valves slightly (turned about one-fourth of a turn) and closing it immediately. This action, called cracking, clears the valve of particles which would otherwise enter the regulator. After cracking the valve, then open it slowly and fully each time you use the nitrogen gas. Do not use compressed gas from a cylinder without reducing the pressure through a regulator designed for this purpose. Do not reduce pressure by throttling the cylinder valve.

Personal Protection. All persons handling compressed gases must wear adequate eye protection, glasses, or face shields. When you handle compressed gas cylinders, you should wear safety shoes. Personnel may not enter an area where there is a high concentration of gaseous helium or nitrogen without using an auxiliary source of air for breathing. At least two persons must be present when a pressurizing system is being operated. Where high concentrations of nitrogen may occur, one member of the maintenance team, with proper rescue equipment, should remain in a safe location as an observer. If the valve of a cylinder is hard to turn, make sure that the valve opening is pointed away from your body before exerting greater force to open the valve. Never use compressed gas or air to dust off clothing. When you do this, it can cause serious injury to your eyes or to your body.

Storage. Cylinders should be protected from the weather and should be fastened to the wall with chains to prevent unwanted movement. The storage facilities should have adequate ventilation. Nitrogen gas is odorless and colorless, and it can cause asphyxiation without warning. If the storage location creates a hazard to personnel, barricades must be erected. When they are frozen or fixed to the ground, never use pry bars under valves or their protective caps to pry cylinders loose.

Shipping. Nitrogen is classified by the ICC as nonflammable gas and requires a green label for shipping. Cylinders used for shipping high-pressure gaseous nitrogen must meet ICC specifications. Personnel handling tanks must display appropriate caution signs in the vicinity of cylinders that are being unloaded.

Anyone handling pressurized Air Force cylinders must avoid bumping or striking the valves when protective caps are not in place. If you must exchange empty cylinders for full cylinders, do not move the containers by their valves or protective caps. Cylinders can be lifted and moved with a crane or mechanical lift but only when racks or cradles are used. Never use rope or chain slings. At no time should you use electromagnets to lift and move cylinders. Even though empty, never use cylinders as rollers or supports. Such abuse may cause cylinder valve damage or dirt or oil contamination, and either can contribute to future accidents and danger to handling personnel. Always consider every cylinder as being full and handle it with care at all times to prevent accidents. Do not drop cylinders or allow them to strike each other or any other object. Never use excessive force to open or close compressed gas cylinder valves. Excessive force can damage the seating material of the valve and allow the compressed gas to leak out slowly. Some cylinders have handwheels that require wrenches or a key to turn the valve, and these tools must always be kept ready for instant use while gas is being used from the cylinder.

Exercises (013):

1. What action should be taken to alleviate possible asphyxiation when storing nitrogen compressed gas?

2. You assign two airmen to move a heavy piece of equipment from one location to another. Later, you check to see how the job is progressing. You find that the airmen are using gas cylinders as rollers to make the work easier.

   a. What damage can be done to the cylinders?

   b. What personal injury could the airmen incur?

   c. How would you remedy this situation?

3-5. Air Force Occupational Safety and Health (AFOSH) Standards

The Air Force conducts a comprehensive and aggressive program to protect all Air Force personnel from work-related deaths and injuries. The Air Force also conducts fire prevention, and health activities that affect the safety and health of Air Force personnel at their workplace. Let's look at how AFOSH applies to AFSC 233X0.

014. State general safety precautions pertaining to an imagery production laboratory.

Imagery Production Laboratory Safety. Mishaps which occur in imagery production laboratories are usually caused by inattentiveness or by a disregard of established, well-known safety rules. You should follow the general safety precautions listed below.

a. General Safety Precautions.

(1) Maintain good housekeeping practices in each area where chemicals are handled.

(2) Appropriate hand cleaners will be available in each area where hazardous chemicals are handled.

(3) Wash rubber gloves thoroughly and promptly with hand cleaner and rinse well with water after each use before removing gloves from hands.

(4) Wash hands thoroughly with hand cleaner and rinse thoroughly with water immediately after handling

poisonous chemicals even though no known contact has occurred.

(5) Scrub rubber facepieces after each use with approved cleaners and rinse well with water.

(6) Clean dust respirators thoroughly and frequently. (See AFOSH Standard. 161–1).

(7) Launder work clothing as needed.

(8) Provide adequate ventilation for processing rooms. *(See AFOSH Standard. 161–2).*

(9) Impress upon maintenance personnel and other visitors the importance of avoiding skin contact with chemicals or chemically contaminated surfaces.

(10) Store all chemicals in cool, dry, dark places. Separate storage areas must be maintained for chemicals which react violently with each other. (For example, do not store potassium permanganate near glycerine.)

(11) Store corrosive chemicals on shelves strong enough to support their loads. These shelves should have copings or ledges to prevent chemical containers and equipment from extending over the edges or from being shoved off the shelves.

(12) Keep all corrosive chemicals in thick-walled glass containers protected by wooden frames or boxes. If the capacity of the container is 5 gallons or more, support the frame by a sturdy wooden or metal cradle, pivoted or hinged for ease in pouring.

(13) Never smoke in darkrooms or in any area where volatile solvents or combustible materials are stored or used.

(14) Electrical equipment will be installed in accordance with the National Electrical Code.

b. Protective Equipment. Requirements for imagery production laboratories will be determined by the supervisor with assistance from the base ground safety and bioenvironmental engineering offices. Gloves, aprons, goggles, and face shields will be worn by all workers as required in AFOSH Standard. 127–31.

c. Eye Wash and Shower Facilities. Imagery production laboratories will have facilities available so workers can flush caustic materials from their eyes or bodies should any be spilled. The need for them will be coordinated through the local safety and bioenvironmental engineering offices.

d. Electronic Flash Equipment.

(1) Electronic flash equipment is designed to work at a high potential, in most cases 450 to 4000 volts; and even after discharge the condensers carry a heavy charge of electricity which must be depleted or "bled off" before any repair work can be attempted. There is the additional danger of sparking of the contact points in the power packs. Precautions listed below are to be followed when servicing and operating this equipment, whether it is in the laboratory, in aircraft, or in other locations.

(2) Only qualified personnel will service high voltage electronic flash equipment.

(3) Do not charge a unit for firing unless the flashlamp is installed and the complete assembly is ready for use.

(4) If the assembly was not fired after is was charged, do not remove the flashlamp for at least an hour.

(5) Never operate this equipment where there is a possibility of the presence of explosive vapors, dusts, or fumes.

(6) Disconnect the power cord from the power pack before removing the lamp or touching the metal part of the lamp socket.

(7) Before removing the batteries, be sure that the assembly has been discharged and that the charging switch has been changed from the CHARGE position.

(8) Allow at least 72 hours for the safety bleeder to deplete the charge before permitting the removal of a broken tube from strobe equipment. Stored up energy from electronic flash units can be lethal. Dependent upon the rate of discharge, this amount of current could severely burn or even kill a person—so know the potentialities of the unit and be guided accordingly.

Exercises (014):

1. Who determines the imagery production laboratory requirement for protective equipment?

2. Why should an electronic flash be bled before permitting the removal of a broken tube from strobe equipment?

3. How should corrosive chemicals be stored? Why?

3-6. Establishing and Evaluating a Safety Program

As a 5-level imagery production specialist, you will be involved with supervision. One of your supervisory functions will be to observe safety practices. You must establish a new safety program when necessary, and evaluate the new one as well as the old one. You must set up and evaluate the safety features of your area, section, or maybe the whole processing facility.

015. List the eight supervisory responsibilities in establishing and evaluating a safety program and specify procedures to carry it out.

Eliminating Hazards. Your first responsibility and your primary task for establishing a safety program are to train all personnel in proper safety procedures in order to eliminate hazards. Personnel under your supervision should not be punished for violating a safety standard if they have not been trained in its proper procedures. For instance, if you have people who continually leave the paper trimmer blade up, you should not punish them if they have not been trained to leave the blade down and locked. Also, you should not fix blame on your subordinates for an accident if you have failed to take preventive measures to eliminate the hazards causing the accident. For example, if one of your subordinates trips over a threshold strip in the lab and spills $40 worth of developer, you should not punish that subordinate for this act. The accident occurred because of failure to eliminate the physical hazard. Therefore, punitive action is justified only after you have trained all personnel and taken action to eliminate physical hazards.

Making Day-to-Day Observations. As a supervisor, you have unlimited opportunities to watch for "near misses," or "accidents in the making." That is, you should look for the unsafe acts of your workers or unsafe mechanical and physical conditions that workers knowingly or unknowingly allow to exist. Your day-to-day observations will (1) reveal unsafe practices and conditions and (2) help identify "close calls" that interrupt production. When you observe these practices, they should indicate to you that something is wrong. They are the symptoms, not the "diseases," and you need to evaluate the situations and treat the causes.

Let's look at some other examples. Suppose you notice Airman Mack changing the bulbs in a contact printer while it is still plugged in. Or you might observe Airman Jones draping the cord for a projection printer over a chair. When you question them, Airman Mack says, "When I change bulbs, I always leave the printer plugged in." Airman Jones tells you that the lights don't work when the cord lies flat. Both of these actions indicate that something is wrong. When you investigate these symptoms further, you discover that Airman Mack leaves the contact printer plugged in so that he can see which bulbs to replace. Airman Jones drapes the cord over the chair because the cord has been broken. She discovered that when it is draped over a chair, the break does not affect the circuit.

To correct these two examples of unsafe practices and conditions, teach Airman Mack how to replace a bulb properly, and tell Airman Jones to report equipment malfunctions as soon as they occur. Additionally, these are only two examples of conditions in your day-to-day observations that could lead to accidents.

Conducting Inspections. One of the best ways to ensure compliance with standards is through frequent inspections. Our problem with inspections, either inhouse or from staff agencies, is that we become apprehensive about being inspected. Members of an inspection team tell us their purpose is only to help, but we sometimes feel they are not too convincing. We may tell them we are glad to have them but we are even less convincing. This is because inspection visits can be trying times, especially when inspectors identify and record our faults. No matter how you feel about inspections, you must remember that inspections are valuable in making your organization effective. They also play a valuable role in establishing and evaluating your safety program. They may be official inspections by base safety and fire personnel or self-inspections that help you solve problems before the inspector general (IG) does. Once you have your safety program established, you must use inspections to evaluate it.

When you inspect your lab for safety hazards, always perform a thorough inspection. Look for the obvious as well as the hidden indicators. For instance, a wad of paper towels stuffed behind a safelight indicates shoddy housekeeping. It also indicates that the bracket is loose and the towels are keeping it from falling off the wall.

Making a Job Safety Analysis. This is simply a system that you use for analyzing and describing each job in terms of duties performed, tools and equipment used, sequence of operations, and working conditions. This analysis helps you to develop the most efficient and safest way of doing a specific job.

Establishing Standards. You must establish job safety standards for each shop or activity. You should design the standards to prevent accidents by identifying (1) the protective equipment and tools used, and (2) the necessary safety precautions used by personnel while they are performing a specific job or task.

The standards in your processing lab must deal obviously with chemical, electrical, and mechanical safety. You need additional standards, since much of your work is done with subdued illumination or in total darkness. After establishing standards, ensure that your personnel are trained, and ensure that they follow the standards.

Investigating and Reporting Accidents. When you investigate and report an accident, avoid your natural inclination to whitewash your own shortcomings or those of your subordinates. Report honestly. Don't conceal deficiencies that may continue to cause accidents. Find the real cause of the accident, and once you find the real cause, you can do something about it.

Dealing With Violations. If an accident occurs, or if one has not occurred but a safety standard or regulation has been violated, you should take corrective actions to prevent a repetition. Counsel or retrain the person responsible and reevaluate the environment to determine what factor contributed to the violation. If you find that certain factors did contribute to the violation, either eliminate them or do what you can to reduce their effect. You may need to reevaluate your safety program, and take steps to change it.

Maintaining an Ongoing Safety Program. It is unfortunate that the cause-behind-the-cause of many accidents is often the failure of the supervisor to fulfill his or her responsibilities in maintaining a safety program. For example, an airman may inhale chemical powder while working with a chemical mixture. This happened because the airman did not wear a face shield or respirator mask. The negligence on the airman's part may be because the supervisor didn't tell the airman to wear the protective device. Remember: (1) You must evaluate existing conditions in order to maintain a viable safety program, and (2) you must evaluate your program to ensure it is working at all times.

Exercises (015):

1. What are the eight supervisory responsibilities that you must consider when you establish and evaluate your safety program?

016. Identify imagery production lab safety programs and procedures.

Methods and Procedures. A major part of establishing a safety program is the use of motivational methods. You must get all of the people interested in the program before they know the program and procedures to carry it out. One such motivational and educational method is the effective use of your bulletin board.

Your *bulletin board* should have a green border, because green is the standard color for safety information. You should provide space on the bulletin board for permanent information, such as first aid, accident reporting procedures, and emergency telephone numbers. The bulletin board is an integral part of your established safety program.

The *safety office* on your base periodically distributes safety posters to your work sections. These are often cartoons showing the effects of unsafe practices and conditions. You should place these posters on your safety bulletin board and in strategic locations in the lab. Place the poster that shows specific job-related conditions in the area where the unsafe practice is most likely to occur. For instance, place a slippery floor poster in the chemical mixing area rather than in the roll film printing area.

The *staff agencies* we mentioned earlier are there to help you. Also, the *fire department* can be of great help to you. Ask their assistance in locating potential fire hazards and establishing fire prevention programs.

Every person in your lab should know the location and operation of the fire extinguishers and alarms. Place stick-on labels with emergency telephone numbers on or near all of the telephones. Mark emergency exits and train all personnel in proper emergency evacuation procedures, and assign firefighting duties to each person in the lab. Invite the fire department people to evaluate your fire drills. Train everyone to recognize safety hazards, and emphasize the importance of proper housekeeping. If the lab is clean and orderly, you eliminate many potential safety and fire hazards. Study the following good housekeeping procedures.

- Store flammable materials properly.
- Empty ashtrays and butt cans daily.
- Do not put combustibles in smoking receptacles.
- Do not put smoking articles in trash cans.
- Use metal trash cans.
- Smoking receptacles should have lids.

Evaluation of your safety program is an important aspect of your program. Once you have established a safety program, don't forget to evalaute it. Here are some reasons safety programs fail. Don't let these failures characterize your safety program.

- Failure to use simple, understandable instructions.
- Failure to follow up to ensure compliance.
- Failure to correct a previously identified hazard.
- Failure to give new personnel an orientation briefing.
- Failure to ensure the use of proper protective tools, devices, and equipment.

Exercises (016):

1. Identify each true statement and explain why the others are false.

   a. Motivational methods play no part in safety education.

   b. Green is the standard color associated with safety.

   c. Safety posters should be placed where they are most closely related with the conditions.

   d. Only those people assigned firefighting duties need training in fire safety.

   e. Everyone should be trained to recognize safety hazards.

   f. Smoking material receptables should be well ventilated.

   g. Failure of safety programs can usually be attributed to poor supervision and evaluation.

2. What is an important aspect of your safety program after you have established it?

3. What part do staff agencies, such as the base safety office and the fire department, contribute to your safety program?

CHAPTER 4

Technical Publications

IN PREVIOUS CHAPTERS, we discussed security and safety as they apply to imagery production facilities. You'll find that as you come across unusual situations in safety, security, or management areas within a laboratory, referring to various official publications will guide your thinking and help you solve your problems. You must become familiar with and learn to use technical manuals, training manuals, regulations, commercial publications, and other publications pertaining to operating and caring for laboratory equipment and materials.

You may already have experience in using some of the publications we discuss in this chapter. Nevertheless, an upgrading of your knowledge of available official publications is needed for you to become proficient in their use. Since you must refer to technical manuals for correct instructions on the operation, inspection, and alignment of equipment, it is imperative that you know where to find and how to use the proper publication for the job.

4-1. Air Force Technical Order Publications

There are several hundred publications covering the operation, maintenance, and supply of photographic equipment. Your task of finding desired information would be difficult if you did not know the system of cataloging, indexing, and numbering these publications. These topics are discussed in the paragraphs that follow. Once you have a working knowledge of the use of these publications and procedures, it is relatively easy for you to find the information needed to perform your assigned tasks.

017. Identify typical use of TOs in laboratory operations.

The Air Force Technical Order System. The Air Force TO system is described in TO 00–5–1, *Air Force Technical Order System*. This system includes data and instructions that are published by the Air Force Systems Command (AFSC) and distributed by the Air Force Logistics Command (AFLC) in accordance with provisions of Air Force Regulation 8–2, *Air Force Technical Order System*. Generally, text and illustrations for most of the publications required are prepared by the manufacturers of the equipment under terms of contracts and in accordance with Government specifications. But in some cases, some publications are prepared by the Air Force. When you consider the great diversity, complexity, and worldwide usage of photographic systems equipment, it is easy to see that there must be a well-organized system to furnish vitally needed information to all operating activities.

The TO system makes information available where and when it is needed and in the most economical and efficient manner possible. The groups of publications produced in this area are as follows:

a. Technical manuals.
b. Preliminary technical orders.
c. Automatic technical orders.
d. Time compliance technical orders.
e. Methods and procedures technical orders.
f. Abbreviated technical orders.
g. Index-type technical orders.

This standard system was adopted as the most practical method of compiling the required information. Each of these major groups contains specific information for certain Air Force activities. In your work you are concerned with the technical manual area, since the technical publications in this group contain detailed instructions and information required for the operation, maintenance, inspection, installation, overhaul, and identification of parts/components for the various types of photographic systems equipment.

Technical Manuals. Technical manuals are grouped into main categories covering aircraft, missiles, and space systems, ground communications and electronics, photographic systems, and other equipment. These technical manuals are referred to in the field as *technical orders*, or simply TOs. These technical manuals have titles such as *Operation and Service Instructions and Illustrated Parts Breakdown*. Actually, the subject titles of all types of technical manuals are quite broad, but these two contain the information and instructions that you will need the most in performing your assigned tasks.

The operation and service instructions technical manuals provide a general description of the equipment, a detailed description of the component parts (or assemblies), the operation preparation instructions, the operating instructions, and the servicing instructions. The service instructions contain information pertinent to periodic inspection, maintenance, and lubrication of the components in the item of equipment. Some of these technical manuals also include troubleshooting and calibration instructions.

The illustrated parts breakdown (IPB) technical manuals contain component part breakdowns that are used for identifying, requisitioning, storing, and determining disassembly and reassembly sequence. Each component parts breakdown lists part numbers, nomenclature and other information necessary to support the item of equipment. Also included are illustrations of assemblies and subassemblies which identify in detail each component part.

Other subject titles of technical manuals and the coverage they contain are as follows:

a. Operation Instructions. These manuals describe a specific item of equipment, its component parts, the operation procedures, and other characteristics to give you sufficient information to operate the equipment.

b. Operation. Service, and Repair Instructions. In addition to describing component parts, operation procedures, and other characteristics, these manuals contain instructions for equipment repair, inspection, lubrication, and adjustment.

c. Overhaul Instructions. These manuals describe equipment characteristics and provide detailed instructions on how to disassemble and reassemble major components.

d. Overhaul Instructions With Parts Breakdown. In addition to instructions on disassembly and assembly, these manuals contain breakdowns used for identifying, requisitioning, storing, and determining assembly and disassembly sequence.

e. Inspection Instructions. These manuals contain requirements for maintenance inspection and replacement of accessories and components.

Exercises (017):

1. From the list of tasks that follow, identify the tasks that should not be accomplished without using the applicable technical order for guidance.

   a. Operating a new piece of equipment.

   b. Daily cleaning of a familiar piece of equipment.

   c. Modifying a printer.

   d. Chemically certifying a processor.

2. What type technical manual would you need to find the following?

   a. Information on the assembly sequence for a new printer.

   b. Troubleshooting instructions for a processor.

018. Specify the types of technical order indexes used in photographic facilities.

Index-Type Technical Orders. This group of technical order publications—indexes—is an important item in your work. Even though you might have had experience with technical orders, the problem of finding the technical manual you want still exists. This problem can be solved easily by consulting the proper index. There are a number of indexes, but the one that you are concerned with first is the numerical index and requirement table that contains a listing of all photographic equipment technical manuals. To find the required numerical index and requirement table, you must refer to a general index that lists all available indexes.

The 0–1–0, *Numerical Index and Requirement Table*, is called the index to "indexes." It includes a listing of all numerical index and requirement tables in addition to listing the *Alphabetical Equipment List Cross Reference Index* (0–2–1).

A numerical index and the requirement table has been published for each specific category of equipment. As shown in figure 4-1, these indexes bear technical order numbers 0–1–1–1, *General Aircraft and Missile Technical Orders*, through 0–1–50, *Special Service Equipment Technical Orders*. However, the index that you are primarily concerned with is 0–1–10, *Photographic Equipment, Supplies, and Sensitized Materials Technical Orders*. All photographic systems equipment technical manuals are listed in this index.

Numerical index and requirement tables are used also to determine availability and status of applicable publications, to requisition applicable publications, and to maintain current technical publication files.

In addition to the 0–1–10 numerical index, you may refer occasionally to the alphabetical index, 0–2–1. The publications in the alphabetical index are listed under alphabetically arranged captions that indicate items of equipment by their basic or primary names. It provides an easy method for locating the correct technical order group when only the type of equipment is known.

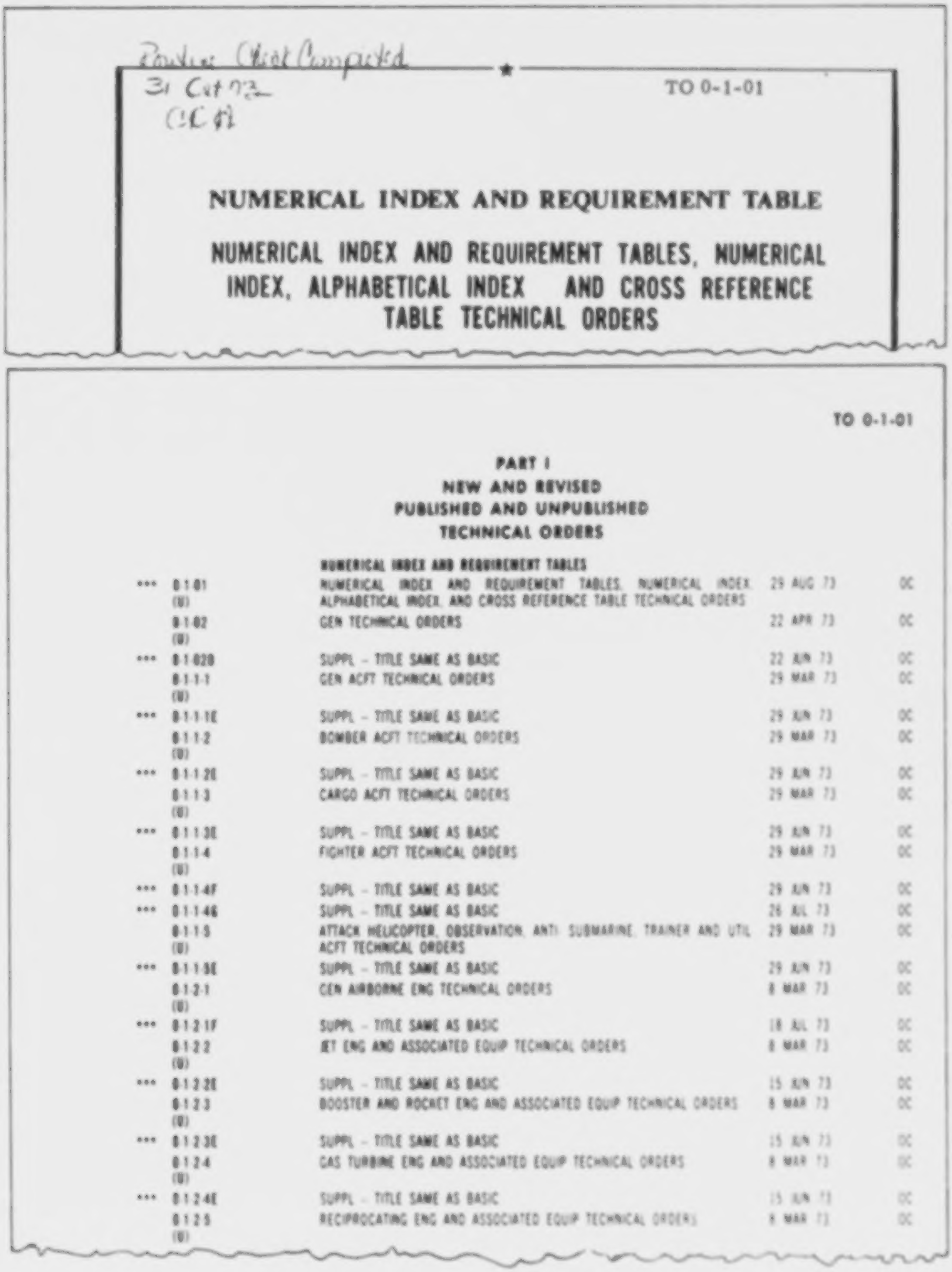
Exercises (018):

1. Describe what each of the following indexes is:

   a. 0–1–01.

   b. 0–2–1.

   c. 0–1–10.



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TO 0-1-01

NUMERICAL INDEX AND REQUIREMENT TABLE

NUMERICAL INDEX AND REQUIREMENT TABLES, NUMERICAL INDEX, ALPHABETICAL INDEX AND CROSS REFERENCE TABLE TECHNICAL ORDERS

TO 0-1-01

PART I
NEW AND REVISED PUBLISHED AND UNPUBLISHED TECHNICAL ORDERS

		NUMERICAL INDEX AND REQUIREMENT TABLES		
***	0-1-01 (U)	NUMERICAL INDEX AND REQUIREMENT TABLES, NUMERICAL INDEX, ALPHABETICAL INDEX, AND CROSS REFERENCE TABLE TECHNICAL ORDERS	29 AUG 73	OC
	0-1-02 (U)	GEN TECHNICAL ORDERS	22 APR 73	OC
***	0-1-02D	SUPPL – TITLE SAME AS BASIC	22 JUN 73	OC
	0-1-1-1 (U)	GEN ACFT TECHNICAL ORDERS	29 MAR 73	OC
***	0-1-1-1E	SUPPL – TITLE SAME AS BASIC	29 JUN 73	OC
	0-1-1-2 (U)	BOMBER ACFT TECHNICAL ORDERS	29 MAR 73	OC
***	0-1-1-2E	SUPPL – TITLE SAME AS BASIC	29 JUN 73	OC
	0-1-1-3 (U)	CARGO ACFT TECHNICAL ORDERS	29 MAR 73	OC
***	0-1-1-3E	SUPPL – TITLE SAME AS BASIC	29 JUN 73	OC
	0-1-1-4 (U)	FIGHTER ACFT TECHNICAL ORDERS	29 MAR 73	OC
***	0-1-1-4F	SUPPL – TITLE SAME AS BASIC	29 JUN 73	OC
***	0-1-1-4G	SUPPL – TITLE SAME AS BASIC	26 JUL 73	OC
	0-1-1-5 (U)	ATTACK HELICOPTER, OBSERVATION, ANTI SUBMARINE, TRAINER AND UTIL ACFT TECHNICAL ORDERS	29 MAR 73	OC
***	0-1-1-5E	SUPPL – TITLE SAME AS BASIC	29 JUN 73	OC
	0-1-2-1 (U)	GEN AIRBORNE ENG TECHNICAL ORDERS	8 MAR 73	OC
***	0-1-2-1F	SUPPL – TITLE SAME AS BASIC	18 JUL 73	OC
	0-1-2-2 (U)	JET ENG AND ASSOCIATED EQUIP TECHNICAL ORDERS	8 MAR 73	OC
***	0-1-2-2E	SUPPL – TITLE SAME AS BASIC	15 JUN 73	OC
	0-1-2-3 (U)	BOOSTER AND ROCKET ENG AND ASSOCIATED EQUIP TECHNICAL ORDERS	8 MAR 73	OC
***	0-1-2-3E	SUPPL – TITLE SAME AS BASIC	15 JUN 73	OC
	0-1-2-4 (U)	GAS TURBINE ENG AND ASSOCIATED EQUIP TECHNICAL ORDERS	8 MAR 73	OC
***	0-1-2-4E	SUPPL – TITLE SAME AS BASIC	15 JUN 73	OC
	0-1-2-5 (U)	RECIPROCATING ENG AND ASSOCIATED EQUIP TECHNICAL ORDERS	8 MAR 73	OC

Figure 4-1. Numerical index and requirement.

019. Given a list of subjects or conditions, identify the type technical order in which these subjects or conditions are found.

Preliminary Technical Orders. These technical orders are produced to test and to verify procedures against first test or early production models of the equipment. They normally are prepared in a limited quantity. Preliminary technical orders are *not* used for operation and maintenance by operating commands except when specifically authorized. However, they may be used for training purposes.

Automation Type Technical Orders. This type of technical order consists of data relevant to operating special device equipment, such as tapes and cards in digital form. When used, these TOs reveal immediate analysis and performance results of systems equipment.

Time Compliance Technical Orders (TCTOs). These publications provide instructions for making one-time changes or for making a record of one-time changes (record-type technical orders) in equipment that may or may not be in service at the time. In addition, these publications impart precautionary instructions relating to flight safety or inspection of equipment. Compliance with these technical orders is required within specified time limits.

Methods and Procedures Technical Orders. Publications of this type provide information and instructions, usually for administrative and supervisory personnel, concerning subjects such as technical order system; maintenance management system; standard and special procedures; air evacuation; arctic, desert, and tropic operation and maintenance; and protective packing and preservation packaging. Methods and procedures technical orders are printed in the same format as aircraft and equipment technical manuals. However, the identification number of methods and procedures technical orders starts with a double zero (00) and is followed by an assigned series number—5 (technical order system), 20 (maintenance management system), 35 (administrative technical orders), etc.

Abbreviated Technical Orders. These publications are primarily work-simplification devices to aid personnel in carrying out the instructions contained in other types of technical orders. Also included within this group are technical orders used for special purposes, such as bombing tables. Following are the various publications included in this group: inspection workcards, inspection sequence charts, inspection worksheets, lubrication charts, bombing tables, and flightcrew checklists.

Exercises (019):

1. It has been found that the present method of arming conventional bombs could result in the bombs exploding. The detailed new arming method would probably be announced in what type technical order?

2. Your laboratory just received a new processor for testing purposes. If a technical order accompanied the processor, what type would it most probably be?

3. Material deficiency reporting on equipment would be contained in what type of technical order?

4-2. Numerical Index and Requirement Table

Much information of vital importance to your work is hidden between the covers of those technical manuals listed in index and requirement table 0-1-10, *Photographic Equipment, Supplies, and Sensitized Materials Technical Orders*. Now the question is, how do we find the proper technical manual? Part of this procedure is to decipher properly the numbering system that is used. Thus, before discussing how to use the index, let's discuss the numbering system.

020. Identify the technical order containing operating procedures for common photographic equipment by referring to reproductions of selected pages from a TO index.

Technical Order Numbering System. The TO numbering system provides for logical grouping of all publications. The most general grouping assigns a TO to a TO category as shown in figure 4-2.

The TO category is designated by a number (usually one or two digits). Within the TO category, the TOs are classified as being of a major group of equipment. The major group is designated by a capital letter. A further division identifies the equipment as a specific type within the major group. The specific type is designated by a number. The combination of the TO category designator, the major group designator, and the specific type designator is the first part of the TO number.

When a TO number has four parts, the second part is a numerical designator identifying the specific item; the third part is a numerical designator identifying the general series, type, model, or part number; and the fourth part is another numerical designator indicating the kind of TO or individual publication. If a three-part TO number is used, the second part in a four-part number is omitted. In either case, dashes separate the parts of the TO number. The general series of each major group is restricted to publications containing general instructions such as cleaning or storage instructions.

Keeping this in mind, let's discover how a technical manual on photographic equipment that falls under the scope of the Air Force technical order system is identified. Materials under the general heading of "Photographic Equipment, Supplies, and Sensitized Materials Technical Orders" have been grouped and numbered. Each TO number for photographic systems technical manuals is

2:1

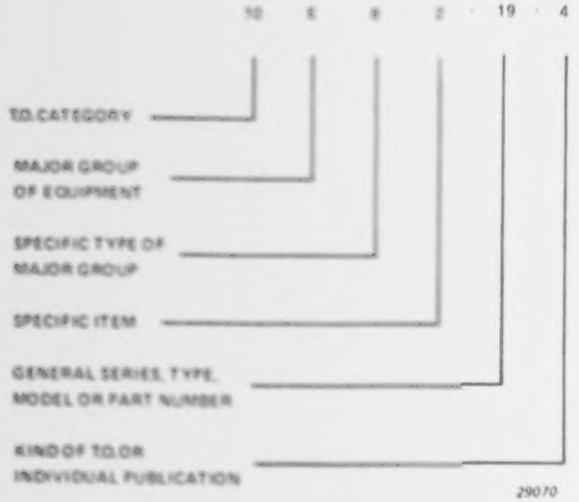

10 E 8 - 2 - 19 - 4
T.O. CATEGORY
MAJOR GROUP OF EQUIPMENT
SPECIFIC TYPE OF MAJOR GROUP
SPECIFIC ITEM
GENERAL SERIES, TYPE, MODEL OR PART NUMBER
KIND OF T.O. OR INDIVIDUAL PUBLICATION
29070

Figure 4-2. Technical order grouping.

divided into three or four parts, and each part, in turn, is separated by dashes. Each part of the TO number denotes certain information. For example, the TO number for the illustrated parts breakdown of the Mark II R5 contact printer is 10E8-2-19-4. Note that there are four major parts to this TO number. The information contained in this TO number is as follows:

a. The first part, 10E8, indicates the general category, the major group, and the specific type within the group. The "10" identifies the general category as Photographic Equipment, Supplies, and Sensitized Materials. The E identifies the major group as Processing Equipment. The "8" identifies the specific type as Printers.

b. The second part indicates the specific item within the specific group. The "2" identifies the printer as a contact (manual) printer.

c. The third part indicates the model or series number. The "19" identifies the contact (manual) printer as Mark II R5.

d. The fourth part indicates the type of publication, such as operation and service instructions, overhaul instructions, etc. The "4" identifies the publication as Illustrated Parts Breakdown (Contact Printer, Mark II R5, Manufacturer).

If the TO number were only a three-part number, such as 10E8-2-1, the breakdown would be the same, except that the second part would be included with the third part.

As you can see, each number of a TO manual specifies a certain classification of equipment, and each letter or number must be identified carefully. The final part of each TO number reflects the type of publication as follows:

a. Operating instructions: –1, –11, –21 through –491.

b. Service instructions: –2, –12, –22 through –492.

c. Illustrated parts breakdown: –4, –14, –24 through –494.

d. Inspecting requirements: –6, –16, –26 through –496.

e. Installation instructions: –7, –17, –27 through –497.

f. Checkout manuals: –8, –18, –28 through –498.

g. Time compliance technical orders: –501 and higher.

Whenever a combined handbook exists, the first type of instructions reflected in the title determines the final part of the TO number. This can be illustrated best with the following example:

a. 10B1–7–1–31, *Operation, Service, and Overhaul Instructions With Parts Catalog—Shutter Assembly With Lens (f/9.5) Wide Angle Lens and Number 3 Betax Shutter (Wollensak).*

b. 10E8–2–5–11, *Operation and Service Instructions—Contact Printer, Type A–14A (Morse).*

c. 10B1–9–2–13, *Overhaul Instructions With Illustrated Parts Breakdown—Identification Still Picture Camera, Model KE–3(2) (Burke and James).*

d. 1–E3–2–9–33, *Overhaul Instructions with Illustrated Parts Breakdown—Photo Film Dryer, Type EL–4(3) (Johnke).*

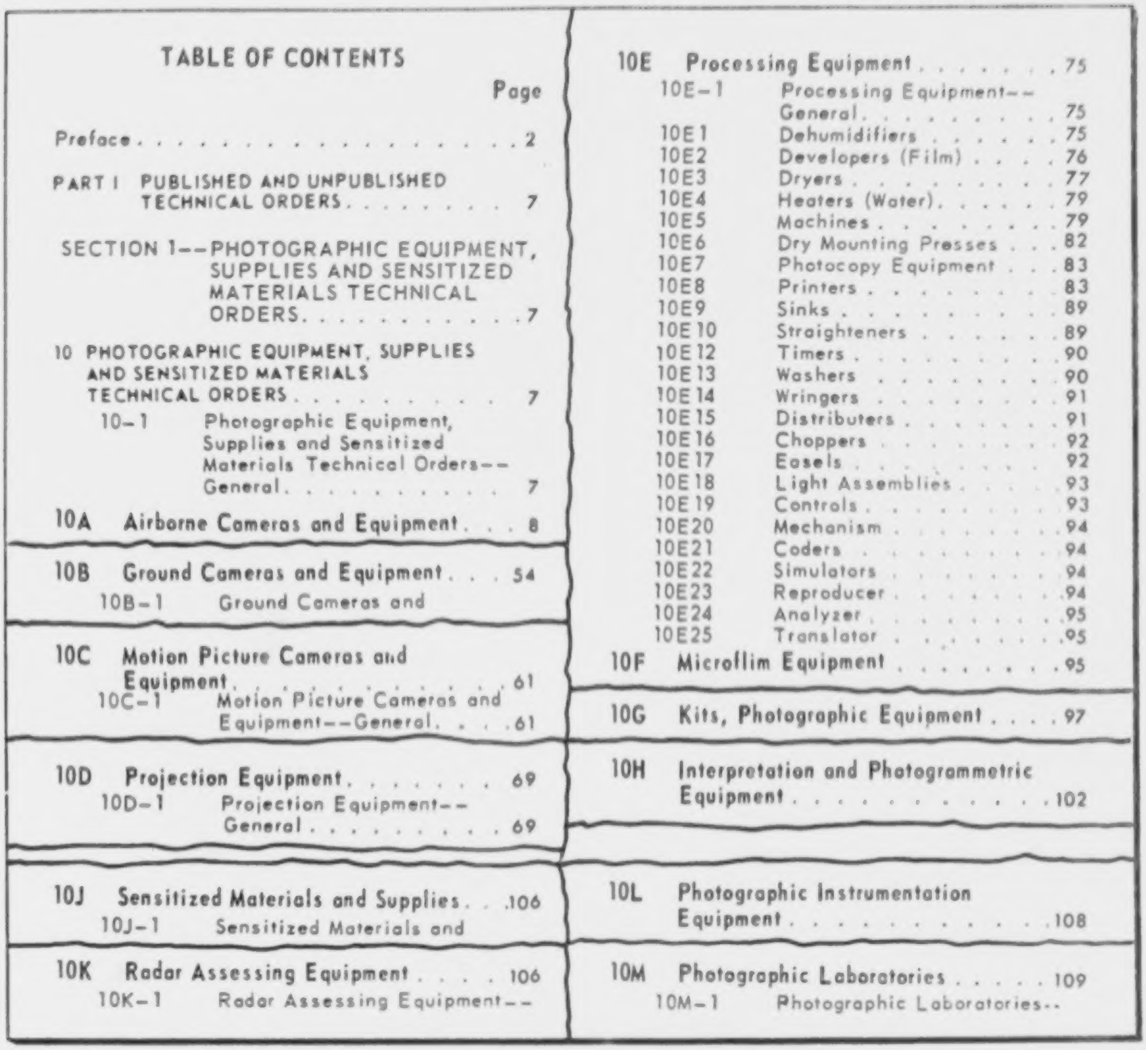
Utilizing the Numerical Index 0–1–10. You have learned that the first step in locating information about any item of photographic systems equipment is to consult TO 0–1–10. When using this index, you should turn to the table of contents and locate the major group of publications you want. The actual number of major groups shown in figure 4-3 is as follows:

Major Group	*Title*
10A	Airborne Cameras and Equipment
10B	Ground Cameras and Equipment
10C	Motion Picture Cameras and Equipment
10D	Projection Equipment
10E	Processing Equipment
10F	Microfilm Equipment
10G	Kits, Photographic Equipment
10H	Interpretation and Photogrammetric Equipment
10J	Sensitized Materials and Supplies
10K	Radar Assessing Equipment
10L	Photographic Instrumentation Equipment
10M	Photographic Laboratories

Let's assume that you are looking for the technical manual that contains information and instruction on the operation of a standard piece of processing equipment. By consulting the list of major groups, you can determine what group the information can be found in.

The next step in locating the desired TO is to determine the subgroup of publications. In the table of contents in the 0–1–10 index, you will note that each of the major groups listing the photographic equipment, the supplies, and the sensitized materials technical orders is broken down into subgroups, as shown in figure 4-3.

Referring to the list of subgroups under Processing Equipment in figure 4-3, you see that the first part of the desired TO number and the page where this subgroup of TOs can be found is indicated. Upon turning to this page, you would look under the general heading until you find the specific type of equipment.



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10L Photographic Instrumentation Equipment 108

10M Photographic Laboratories 109

10M-1 Photographic Laboratories--

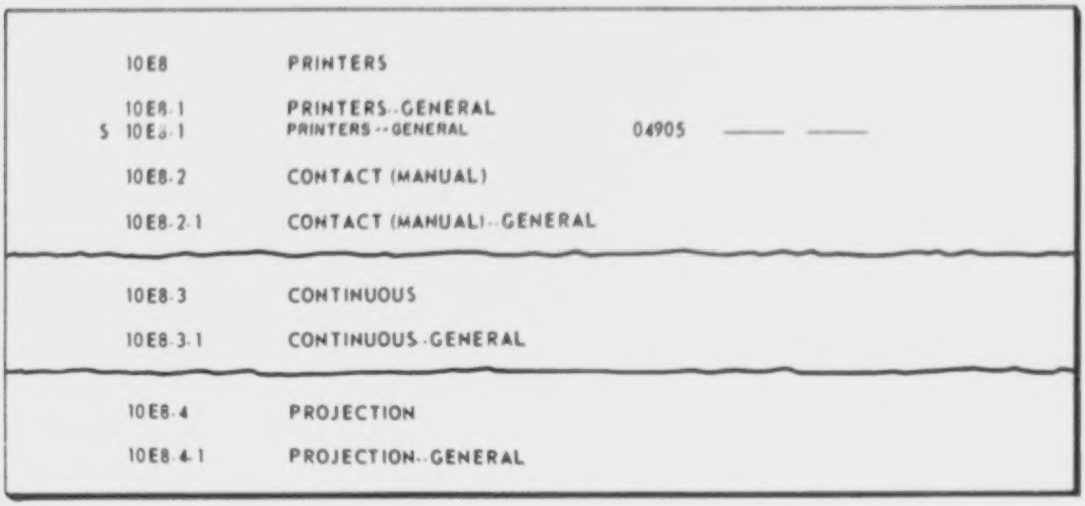
Figure 4-3. Major groups and subgroups.

Next, assuming that there is more than one type of the equipment (contact, projection, continuous printers), select the specific type from those listed. This identifies the next digit in the TO number.

The final step is to scan the general series until you locate the specific type. Usually, there are three types of technical manuals listed under each series. These are operation and maintenance instructions, overhaul instructions, and an illustrated parts breakdown. Refer to figure 4-4.

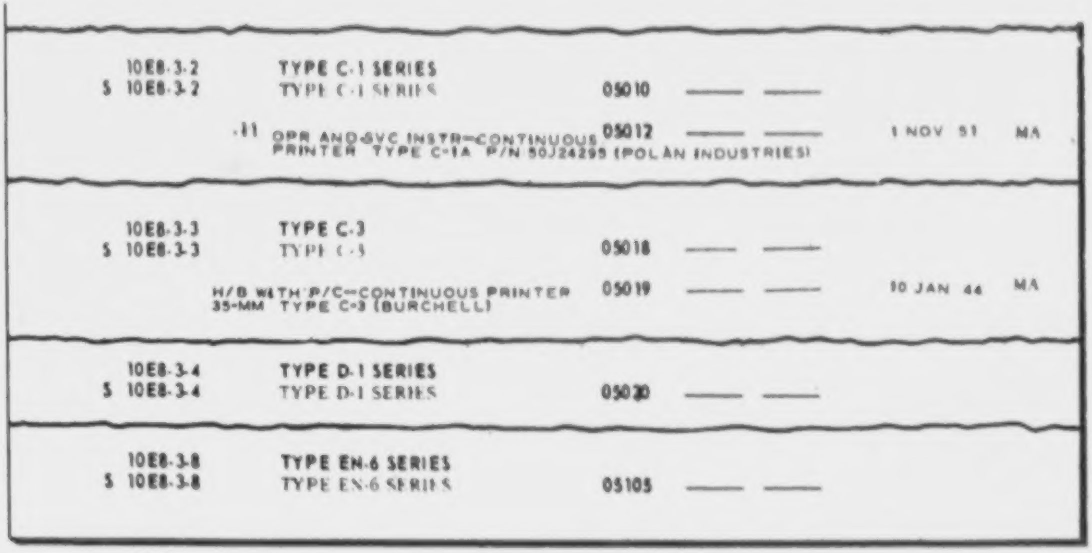
Now that you know the number of the desired technical manual, you can obtain it from your TO library. To locate the operating instructions in this technical manual, you simply turn to the table of contents in the front of the technical manual and scan the listing until you find the numbered section that contains the operating instructions. Refer to figure 4-5.

It is doubtful that you will become an expert on the TO numbering system merely by reading this material. But if you combine what you learn here with the actual practice of searching out the technical manuals for specific items of equipment, you will soon become proficient. Refer to figure 4-6.



```
     10E8        PRINTERS

     10E8-1      PRINTERS--GENERAL
   S 10E8-1      PRINTERS--GENERAL               04905   ____   ____

     10E8-2      CONTACT (MANUAL)

     10E8-2-1    CONTACT (MANUAL)--GENERAL
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
     10E8-3      CONTINUOUS

     10E8-3-1    CONTINUOUS-GENERAL
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
     10E8-4      PROJECTION

     10E8-4-1    PROJECTION--GENERAL
```

Figure 4-4. Specific types within a subgroup.



```
     10E8-3-2    TYPE C-1 SERIES
   S 10E8-3-2    TYPE C-1 SERIES                 05010   ____   ____

            -11  OPR AND SVC INSTR—CONTINUOUS    05012   ____   ____      1 NOV 51    MA
                 PRINTER  TYPE C-1A  P/N 50J24295 (POLAN INDUSTRIES)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
     10E8-3-3    TYPE C-3
   S 10E8-3-3    TYPE C-3                        05018   ____   ____

          H/B WITH P/C—CONTINUOUS PRINTER        05019   ____   ____      10 JAN 44   MA
          35-MM  TYPE C-3 (BURCHELL)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
     10E8-3-4    TYPE D-1 SERIES
   S 10E8-3-4    TYPE D-1 SERIES                 05020   ____   ____
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
     10E8-3-8    TYPE EN-6 SERIES
   S 10E8-3-8    TYPE EN-6 SERIES                05105   ____   ____
```

Figure 4-5. General series of specific type.

Exercises (020):

1. Using figures 4-3, 4-4, 4-5, and 4-6, determine the TO containing the operating instructions for the type EN-86A continuous contact printer.

2. Using figures 4-2, 4-3, and 4-4, determine the TO needed for the EN-6 continuous contact printer.

   a. Figure 4-2.

   b. Figure 4-3.

   c. Figure 4-4.

		CONTINUOUS CONTACT PRINTER, SERIAL NUMBER 400 THRU 503, TYPE EN86A (NIAGARA PRINTER, EK P/N 1 008E001) (EASTMAN KODAK)		
	10E8-3-10-1 (U)	OPR AND SVC INSTR	1 APR 68 CHG 5, 27 NOV 72	00
	10E8-3-10-3 (U)	O/H INSTR	1 APR 68 CHG 7, 1 DEC 74	00
	10E8-3-10-4 (U)	IPB	1 APR 77	00
		P/N 3, 3K		
K	10E8-3-12-4 (U)	IDENTIFIES A COMMERCIAL MANUAL TITLED P/C -DEPUE OPTICAL REDUCTION MOTION PICTURE PRINTER, P/N 3, 3K LIGHT CONTROL (NOT DTD) (OSCAR F CARLSON)	1 MAY 68	00

28010

Figure 4-6. Types of typical manuals.

3. Using figure 4-5, what TO is needed for the EN-6 continuous contact printer to:
   a. Load and thread film.
   b. Disassemble film drive clutch assembly.
   c. Requisition parts.

4. The basic principle of the TO numbering system is to provide a specific category to be separated into major groups. Explain the underlined number or letter in TO 10E8-2-19-4.
   a. 10.

   b. 10E.

   c. 10E8.

   d. 10E8-2.

   e. 10E8-2-19.

   f. 10E8-2-19-4.

f. 10E8-2-19-4.

4-3. Air Force Regulations,, Operating Instructions and Commercial Publications

Regulations, operating instructions, commercial publications, and even this CDC have something in common. They are all publications. As part of your administrative duties, you may be called on to order, maintain, and use publications. Just having them in a pile in someone's desk will not hack the program. There are established procedures you must follow to keep your publications in order. The first set of publications we will cover are regulations.

021. Given descriptive statements about regulations, identify what they are used for.

Air Force Publications (AFRs). In anything you do, you must follow certain rules. You might be driving your car, playing golf, or typing a letter. The point is, there are always rules for you to follow. Air Force life is no different. The purpose of Air Force regulations should be obvious: to ensure each job is done properly and uniformly. You wouldn't want the Bronco's playing field to be of different dimensions than the rest of the NFL fields. Likewise, you wouldn't want the instructors at Lowry to teach Imagery Production in a way different from how it is performed at your base.

Regulations are the primary administrative publications that govern the Air Force. They are used to assign responsibilities, announce policies, direct actions and prescribe procedure. They are usually permanent in nature and usually consist of only a few short pages. When it is known that a regulation will cease on a specific date, the expiration date is included. Air Force regulations are the most numerous of all Air Force standard publications.

Exercises (021):

1. What are Air Force regulations used for?

022. Define terms relating to maintaining a publications library.

In an effort to advance yourself and in fulfilling your managerial responsibilities, you need to learn how to maintain regulations. Air Force Regulation 5–31, *Publications Libraries and Sets*, contains the basic guidance for you to follow.

Terms Defined. Some of the terms you will use to maintain a regulation file are discussed below.

Publications distribution office (PDO). This office is the focal point on your installation for the receipt and distribution of publications.

Customer account. The PDO assigns a customer account number to each activity it serves to control the distribution of publications.

Customer account representative (CAR). The CAR is the person designated by each unit or staff office to be the official liaison with the PDO. This person tells the PDO which publications the activity needs. When the PDO provides the publications, the CAR distributes them to the subaccounts within the activity.

Master publications library. This is a centralized repository of standard and specialized publications. It provides a readily available reference service to all activities at your Air Force base. It contains a copy of nearly every unclassified publication issued by (1) each higher headquarters of the maintaining activity; (2) the headquarters or organization maintaining the library; and (3) subordinate, attached, or tenant units. It does not contain every publication because the unit may not need each and every publication.

Functional publications library. This is the unit or staff office file which contains only those publications which are needed to perform the mission in a specific functional area. The functional publications library contains only those publications that specifically apply to the technical and administrative responsibility of the organization that maintains it. A copy of AFR 5–31 must be in this library.

Individual publications set. This is a single publication or group of publications that relates directly to the duties of the holding individual and to which he must refer frequently. This set contains those regulations that apply specifically to the daily operations of the user. So if you had only an occasional need for a regulation, you would not have it in your individual set.

Exercises (022):

1. Define the CAR.

2. Define the functional publications library.

3. Define the individual publications set.

023. Define terms, list methods, and resolve problems relating to procedures used to file and post publications.

You will get the publications from the PDO or from your CAR. Regardless of the source, you will be responsible for making sure that you get only those publications you need. When you receive publications that you don't need or too many of those you do need, notify your CAR or PDO immediately.

Filing Publications. Your publications should be filed in 3-ring binders. Each binder may be identified with standard slip-on label holders. Place the publications in the binders in numerical sequence and then put each binder in sequence. The sequence is established by the publication number. For example, 20–3, 20–5, 36–93, 95–4, etc.

All of the publications (except supplements) issued by each headquarters must be kept in separate binders. That is, do not put Air Force, Air Training Command, Tactical Air Command, etc., publications in the same binder.

The publications may be filed by one of two methods. The first is to file them by number. For example, beginning with the first binder, interfile all Air Force regulations, manuals, and pamphlets in numerical order. If two or more publications have the same number, file the regulations first, followed by manuals and then pamphlets. After filing all the Air Force publications, start a new binder with the next organizational level and continue until you have filed all the publications in your chain of command.

Publications may be filed by type. For example, place all Air Force regulations in separate binders; all Air Force manuals in separate binders; all Air Force pamphlets in separate binders; MAJCOM regulations in separate binders, etc. The indexes of each different headquarters may be filed in one binder.

Revisions. When a publication becomes obsolete, it may be revised. When you get a publication, look for the supersession line at the bottom of the first page. If there is no supersession line, you have a new publication and it should be filed in the appropriate binder. If there is a supersession line, remove the old publication and place the revision in the binder.

Changes. Some publications may not need to be revised; they may need to have minor changes made. The change transmittal sheet (front page) will tell you whether to insert new pages, make minor write-in changes, or use a combination of both. AFR 5–31 gives explicit directions on how to make changes.

Supplements. A supplement is a separate publication which is issued to add information to a basic publication so that it can be smoothly implemented in light of local situations. It is designed to be posted to the appropriate paragraphs in the basic regulation and then filed in back of the publication. Here again, you should read AFR 5–31 for step-by-step procedures pertaining to posting supplements.

Posting Publications. When you follow the instructions on the change transmittal sheet by adding or removing pages, or by making write-in changes, you are posting the change. Once you have completed all necessary actions, you have posted the change. You may, although it is not required, annotate the change after you have posted it. For example, write "posted," the date, and your initials at the top of the change.

It is not the intent of this section to make you an administrative specialist. We do feel, however, that you need to be familiar with some of the duties of a publications clerk. If these duties are assigned to you, consult the master functional librarian and/or the following regulations.

AFR 5–1, *Air Force Publications Management Program.*
AFR 5–4, *Numbering Publications.*
AFR 7–2, *Procedural Guide for Customers of the Publishing Distribution Officer*

Exercises (023):

1. Arrange the following Air Force regulations in proper sequence:
   12–32, 35–10, 5–1, 36–93, 25–1, 5–31.

2. What are the two methods of filing publications?

3. In what order do you file two or more publications having the same number?

4. What does a supersession line tell you?

5. What does "posting a change" mean?

024. Give purpose and contents, and clarify procedures related to branch operating instructions.

A regulation will tell you exactly how to do a specific task. But suppose you had to clean a processing shelter and you had previously worked only in the print shelter. You would need a set of instructions that specifically govern each situation. We call these instructions operating instructions (OIs).

Operating Instructions. When personnel report to their new supervisor, he or she usually gives them a book of local procedures (OIs) to follow. They are used to announce policy and to prescribe procedures and can be used at any level of command. Operating instructions are essential for several reasons. First, they identify every task to be performed in the laboratory. Second, they explain the reason for performing the task. Third, they place the responsibility for the performance of the task. Fourth, they outline the complete procedure to be followed to perform the task. Finally, they identify the authority for ordering the task.

As you can see, OIs serve a very useful purpose. They outline the duties of all of the personnel working in your facility, describe the procedures to be followed for every task, and set the standards of quality for the finished products.

Each OI is identified by a title and two-part number. The title identifies a specific area the OI will cover. The first part of the number identifies the general area of coverage and corresponds to the same series number as the regulation, manual, or pamphlet that the OI supplements. For instance, an OI that covers the management of your publications may be BOI 5–1. The 5–series publications deal with publications management. Most of your OIs probably are 95 series since the 95 series of publications deals with the audiovisual systems.

The second number of the OI is assigned chronologically for each OI that is written. For example, you could have OIs from 95–1 through 95–8. This series may have an OI for the processing printing or titling room, etc.

Filling OIs. Your OIs should be filed much like your other publications. Put the master set of OIs in a 3-ring binder in chronological order. This binder should be in a central location where it has maximum availability. In addition to the master set, each section should have the OIs that pertain to that section.

Exercises (024):

1. What are the five things that an OI tells you?

2. What is the purpose of an OI?

3. What would be the number of your first BOI that deals with security?

4. What minimum number of OIs should you have for each area of responsibility?

025. Identify the advantages of using commercial publications.

Commercial technical publications comprise another group of technical manuals that you will be required to use frequently. As with the other technical manuals, commercial publications contain technical information and instructions on assembly, installation, operation, service, disassembly, overhaul, and parts identification. Commercial publications in manual, booklet, or pamphlet form are normally furnished by manufacturers to purchasers of their product.

When you buy a car, you check out the owner's manual carefully to ensure proper operation under all conditions. It would be foolish to think "all cars are the same." The same principles apply to imagery production equipment. All continuous film processors have different operating procedures that vary from model to model. Failure to follow directions can result in damaged equipment and mission failure. You can avoid these results by reviewing your manuals.

Commercial texts are not used just to prevent trouble but are positive aids to help you achieve efficient use of the gear. In fact some manuals amount to a basic photo course since the manufacturer wants the user to get the most from his product. You should take advantage of the wealth of free information that is available. In fact, all the photo manufacturers have technical representatives who may be contacted for information on how to solve many photo problems.

Information is also available on expendable types of supplies. This information may not be in the form of a technical manual. Instead, it may simply be a single-page bulletin. An imagery production specialist should check information continuously to ensure that he or she is taking advantage of changes in film and chemistry. For example, most instruction sheets that come with a batch of chemistry give helpful hints on mixing, processing, and storage parameters. This information is provided so the user can achieve top results from the product. Such an information sheet can be as important as that found in technical manuals.

Exercises (025):

1. The proper use of commercial texts will help prevent what two problems?

CHAPTER 5

Supervision

AS YOU PROGRESS to the 5 and eventually the 7 skill level, you will become more involved in supervising the personnel assigned to your work area and in assuring the smooth operation of the work area itself. Supervising people is a topic so lengthy that it would take several volumes to cover adequately. In fact, various correspondence and resident courses are offered covering the science and art of being a supervisor. This chapter, instead, will deal with the other half of supervision: the operation of the work area to which you have been assigned. Some of the factors with which you will become concerned are environmental protection programs, cleanliness standards, preventive maintenance, and the graduate evaluation program. This last topic, even though it is people oriented, is intended to improve the quality of the work produced at another work area—the technical school.

5-1. Environmental Protection

Environmental pollution is the presence of physical, chemical, and biological elements that adversely affect all living things. It affects human health, alters ecological balances, adversely affects animal and plant life, and causes deterioration of manmade objects. This pollution includes noise, improper solid waste management, and other things conventionally thought of as pollutants.

026. State why environmental protections are necessary.

Environmental pollution is an economic, technical, and social problem. It is a problem because the Earth and its inhabitants have only a limited supply of air and water. When these are gone, or contaminated to the point where they can no longer support life, all living things on Earth as we know them will become extinct. Only recently have we become aware of the consequences of poisoning these two life-sustaining substances. Because of this awareness, much has been done to lay the groundwork for legislation that will be effective for the control of water and air pollution.

Exercises (026):

1. Why is environmental protection necessary?

2. What two prime factors is pollution concerned with?

027. Specify what the Air Force policy is regarding situations that affect the environment.

Environmental Protection. The Refuse Act of 1899 requires that permit be obtained before virtually any substance other than sewage is discharged into most streams, rivers, lakes, or other bodies of water. Failure to do so constitutes a criminal offense. Air Force personnel responsible for violating this act can be prosecuted.

The Clean Air Act requires Federal installations to comply with Federal, state, interstate, and local requirements for the control and abatement of air pollution. This requires more than just meeting air quality standards. For example, it means that it will be necessary to apply for state permits where activities, such as firefighting training, require state approval.

The Air Force policy on environmental protection is as follows:

a. Eliminate or control pollutants generated by Air Force operations.

b. Prevent, control, and abate environmental pollution by accelerating corrective measures at Air Force installations.

c. Provide for environmental pollution control in designs of new buildings, systems, and operations.

d. Provide preventative pollution control by:

(1) Reducing or eliminating waste at the point of generation.

(2) Considering potential environmental pollution control problems when selecting chemical compounds and materials to be used in Air Force operations.

(3) Including pollution abatement as an element in specifications.

e. Comply with criteria and standards published by the Environmental Protection Agency (EPA) and by state and local abatement agencies in the area.

f. Exempt certain facilities in the interest of national security from complying with approved environmental control standards.

g. Dispose of pollutants in a manner that does not expose people, animals, or plants to concentrations that might be hazardous.

h. Ensure that contracts for disposal of waste contain provision which require the disposal methods to be in compliance with Federal, state, or local standards.

i. Establish procedures to prevent cooling water from increasing stream temperature above acceptable limits.

j. Store and handle petroleum products in accordance with Federal, state, and local standards.

k. Minimize the creation of waste.

l. Use local waste disposal systems to dispose of waste.

m. Ensure that all materials are used, stored, and handled to avoid or minimize the possibilities of water and air pollution.

n. Provide the engineering safeguards that are necessary to prevent pollution of water by accidental discharge of stored fuels, solvents, oils, and other chemicals.

o. Assure that discharges or radioactivity conform with the applicable rules, regulations, and requirements of the Atomic Energy Commission and with the policies and guidance of EPA.

p. Give priority in the following order when resources to accomplish pollution control are limited:

(1) Situations that constitute a hazard to the health or safety of man.

(2) Situations that are cost effective.

(3) Situations that affect the recreational and esthetic value of our natural resources.

q. Assure the environmental consequences of any proposed action at the earliest practicable stage in the planning process and in all instances prior to decision.

r. Insofar as practicable, and with appropriate consideration of assigned missions and of economic and technical factors, plan, initiate, and carry out programs and actions to avoid adverse effects on the quality of the human environment.

s. Ensure that oversea installations conform to the same pollution abatement policies that are prescribed for installations located in the United States.

t. To avoid duplication and ensure timely solutions to mutual problems, fully coordinate environmental protection matters with all agencies concerned.

How are imagery production facilities concerned with environmental protection programs? One form of pollution results when any effluent containing silver is discharged into sewers, storm sewers, or streams if the silver content is more than five parts per million. A prime example of this type of pollution is in the disposal of photographic solutions. They not only contain valuable silver, but the chemicals in the solutions pose a contamination problem. Electrolytic devices remove the silver from the solution and a recharging process renders the solution reusable. This minimizes the volume of effluent to be disposed of and contributes substantially to environmental control.

The treatment of film, like the disposal of any waste material, poses another pollution threat—especially if disposition is by burning. In silver recovery, controlled burning devices equipped with afterburners and scrubbers minimize the particulate emission and gases discharged into the atmosphere.

Exercises (027):

1. What would be the Air Force's position concerning the following environmental acts?

   a. The dumping of photographic wastes into Sand Creek located near XYZ Air Force Base.

   b. The recovery of silver from photographic solutions.

   c. The burning of photographic film in an incinerator which meets Federal but not state pollution standards.

   d. The discharge of photographic wastes into a river near Teheran, Iran.

   e. Friendly Air Force Base plans to purchase an incinerator as part of a silver recovery program. GI Joe Army Base, two miles away from Friendly, already has one in operation.

5-2. Equipment Cleanliness

If you were to examine some of the many publications covering the subject of photography, you would notice that often they include a section of defects. A close examination of these lists of defects would show you that many are caused by a lack of laboratory cleanliness.

Some photographic techniques are built around the concept of correcting defects. Rather than correcting the defect, it is preferable to eliminate the cause. Defects are caused by carelessness during one or more phases of the photographic process. You cannot hope to maintain quality control unless you make cleanliness a continuous habit.

028. State why equipment cleaning is necessary.

Most of the physical defects in photographic products can be traced to equipment. These defects can be classified broadly into two categories. In the first, the equipment physically damages the imagery material, causing scratches and abrasions on both the emulsion and base sides. In the second, image degradations occur in the form of decreased sharpness and detail, resulting from the lens, as well as loss of density, contrast, and material sensitivity, resulting from solution contamination.

Exercises (028):

1. What effect might dirty processor rollers have on the film being processed?

2. Why should lenses be kept clean?

029. Identify equipment cleanliness violations and cite the probable results on product quality.

All original imagery products are valuable, and in many cases, cannot be reaccomplished. Therefore, you must make every effort to ensure that these products are not damaged or lost because of poor cleanliness habits. A list of things that you should be constantly aware of is given below. This list does not contain all possible trouble areas, but becoming familiar with your equipment will greatly expand this list.

Processors. The first possible source of trouble in the processor is the transport rollers. As the material travels through the processor, the solutions are picked up by the material and deposited onto the rollers. If there is foreign matter in the solutions, or if the solutions are allowed to dry and crystalize, it is likely that some of these particles and crystals will become embedded in the rollers. Then, during the next processing session, any slippage between the rollers and film will produce scratches.

As the film leaves the wet section of the processor, it passes to the drying section, where there is usually a high circulation of forced air. Any dirt, dust, or other matter in the drying cabinet at that time can be forced into the film emulsion. This material is impossible to remove once the emulsion is dry. In extremely high-altitude reconnaissance products, this defect can completely hide valuable intelligence information.

Another kind of bad housekeeping does not physically damage the photographic material, but it does damage the processor itself. This is allowing the processing solutions to dry on areas of the processor that are not constructed of corrosion-proof material. Prolonged exposure to these solutions can cause serious damage. At best, production time can be lost. At worst, the processor may have to be replaced completely.

Continuous Printers. A special problem exists with high-speed continuous printers. During operation, the supply and takeup spools rotate at a high rpm. This motion sets up air currents that disturb dust particles, causing them to become airborne. If these particles become sandwiched between the negative and duplicating material, they prevent exposure and appear as clear areas in the duplicate. To prevent this defect, the printer should be vacuumed before each printing session. It can be seen that dusting with a brush or dusting cloth only disturbs the dust particles and does not remove them from the area.

Another source of trouble can develop in the transport and idler rollers. After many feet of material have been run through the printer, an emulsion buildup is likely to occur on these rollers. If allowed to remain, this can result in scratches or other abrasions on subsequent printing runs.

Tacky Roller Film Cleaner. This film cleaner operates on the principle of dust and dirt being picked up by the cleaning rollers. This foreign material readily adheres to the gummy substance that the rollers are made of. If the rollers are not perfectly clean at the beginning of the cleaning operation, or if there is an accumulation of dust on the cleaner, it cannot perform the cleaning operation. To clean this piece of equipment, use a vacuum cleaner.

We have discussed only three of the many pieces of equipment found in most imagery production laboratories. Furthermore, we have only touched on the reasons for cleanliness for each of these three pieces of equipment. However, this should be sufficient to show you that equipment must be kept clean if you are to get the greatest possible benefit from it.

Exercises (029):

1. If foreign matter is allowed to become embedded in the processor rollers, what effect would it have on the film?

2. An airman is assigned to clean the tacky roller film cleaner. He uses a brush to remove the dust and places the cover back on the machine. How will this affect the cleaning capability of the machine?

3. What effect can you expect if ME–4 bleach is allowed to dry on the outside of the processor?

5-3. Laboratory Cleanliness

In the previous section, we discussed equipment cleanliness and the possible results if cleaning tasks are not accomplished properly. Now, let's consider laboratory cleanliness.

030. State why facility cleaning is necessary.

The equipment you use to produce the photographic products is capable of producing defect-free products only to the degree of the cleanliness of the surrounding environment. It makes no difference how many times you vacuum the printer or film cleaner or clean the inside of the processor drying cabinet if there are dust, dirt, and dried chemicals on the floor. These materials can become airborne simply from the air currents set up by someone passing through the room. Then, when they settle, they recontaminate the equipment. Therefore, the cleanliness of the facility has a direct effect on your product quality.

Exercises (030.):

1. Why is facility cleaning necessary?

2. Why is it necessary to keep dried chemicals off the floor?

031. Specify situations of facility cleanliness violations, and state the probable causes of resulting poor quality product.

During laboratory cleanup, it is poor practice to use a broom to sweep the floor. It is much better to use a dust mop because it does not throw dust and chemicals into the air. After using a dust mop, use a wet mop and rinse and wring it out frequently. Using a dirty mop does more harm than good.

Rinse sinks thoroughly with clean water to remove all traces of chemicals. Edges and back panels that cannot be flooded with water should be wiped with a clean, damp cloth or sponge. Do not forget to clean chemical residue from walls, benches, tables, and all equipment during lab cleanup procedures. These residues are transferred easily to your hands and subsequently to the surfaces of sensitized materials. Dirt on safelight filters not only reduces effective illumination but also falls onto film and paper to create defects.

After a lab has been cleaned, you should use a vacuum cleaner to remove dust that may have settled into corners. Dust often contains small particles of crystals of quartz, and these can scratch glass surfaces such as printer glasses and lenses.

If a liquid is required to complete the cleaning job, remember that water can eliminate most chemical deposits. When you need to use a solvent other than water, use as little as possible and consider all safety precautions connected with its use. Repeated applications of an excess amount of water on a tile laboratory floor may loosen the tiles.

After you have done as much as you can to maintain the cleanliness of a laboratory, you have gone far toward quality control. Even so, the presence of dust, chemicals, lint, and other particles is always a problem.

Exercises (031):

1. A room that had just been swept is used to process cut film. When the negatives are dried, tiny clear spots are present in each negative. What could have caused these clear spots?

2. Why is it necessary to clean safelights?

5-4. Preventive Maintenance Procedures

The term "preventive maintenance" refers to the normal upkeep of equipment through a series of systematic inspections. Some of the inspections used are the acceptance inspection, in which newly received equipment is checked for completeness and performance; the periodic inspection (or PI), in which items of equipment are checked on a regularly scheduled basis for usage, wear-and-tear, or deterioration; and unscheduled maintenance, in which equipment requires repair as a result of malfunction or breakdown. The first two types of inspection, the acceptance inspection and the PE, will have only an indirect effect on your work. It is the unscheduled maintenance, however, that you will become involved with as an imagery production specialist and supervisor.

032. Explain the meaning of symbols used on equipment maintenance forms and their importance to mission accomplishment.

Equipment Maintenance Forms. It is important to know whether any problems exist on photographic equipment before that equipment is started and put into use. If a problem does exist, it would lead to serious consequences. Unfortunately the previous operator of the equipment is not always available to pass on such information. Instead, equipment maintenance forms are used to check and verify the equipment status before the equipment is used. The three most commonly used forms are the AFTO 244, Industrial/Support Equipment Record, AFTO 245, Continuous Sheet, and AFTO 95, Significant Historical Data.

The location of these forms will vary from one organization to another. In many cases the equipment maintenance forms will be attached directly to the equipment, usually in some sort of protective envelope. In other work areas they may be filed centrally in the maintenance shop or office. Wherever they are located, the forms should be checked before the equipment is touched. Doing so could prevent injury to the operator or damage to the equipment or material being processed.

The two most important items to check are the inspection schedule and the discrepancies, especially the symbol block. The inspection schedule will indicate when the last periodic inspection (PE) took place and when the next one will be due. This information is found in Part III of the AFTO Form 244. The discrepancy area of the equipment maintenance form, Part V of AFTO Forms 244 and 245, tells of any problems discovered during previous operation of the equipment. It also includes a symbol indicating the seriousness of the discrepancy. It is important that you know these symbols and their meaning.

The symbol which indicates the most serious condition is the red X. It tells the operator that the equipment is considered unsafe or unfit for use and that the equipment must not be used until the unsatisfactory condition is corrected. The circled red X indicates that the equipment is pending compliance with an urgent action TCTO and may not be used until the action is complete. The red dash is used when the condition of the equipment is unknown (for example, when a PE is overdue) and a more serious condition may exist. The red diagonal tells the operator that an unsatisfactory condition exists, but it is not sufficiently urgent to warrant not using the equipment. Note that the equipment may NOT be put into use if the discrepancy symbol is a red X or circled red X.

Exercises (032):

1. Name two locations where equipment maintenance forms may be found.

2. What are the two most important items to check on equipment maintenance forms before using the equipment?

3. Arrange the four discrepancy symbols in order from the most serious to the least serious.

033. Given a list of situations relating to equipment discrepancies, write the name, date, symbol, and discrepancy to be entered on the equipment maintenance form.

Annotating Forms. At some time while you are operating processing and/or printing equipment it will be necessary for you to make entries on a maintenance form. Of the three types of AFTO forms mentioned above (the 244, 245, and 95), the one in use by your organization is determined by your major command. However, some basic entries apply to any equipment maintenance forms you may encounter.

a. Item Identification (Part I, AFTO Form 244). The registration or serial number should be copied carefully from the machine itself, not from a previous form. This will prevent a possible error from being compounded. Each item of equipment (or, in some cases, a group of like equipment) will have a six-character ID number. The first two characters will be letters assigned by your major command. The last four characters are determined locally and can be either letters or numbers. Frequently the numbers used are the last digits of the serial number of the equipment. The item will also have a work unit code assigned by the maintenance shop. Your organization will have a work center code assigned. Some forms have a block for the period of time covered by the form itself.

b. Service Inspection (Part II, AFTO Form 244). One part of the form may contain a section for daily service inspections. This allows you, the operator, to enter your initials and the date and time of the inspection each time you start the equipment. This area serves to indicate the last time the equipment was used and the operator who used it. If the forms used in your work area contain this block, be sure to fill it out each time you use the equipment.

c. Inspection Record (Part III, AFTO Form 244). This part of a maintenance form indicates the next scheduled PE, the frequency of PE inspections and when the last PE was accomplished. It is useful for planning purposes and indicates when an item is overdue an inspection. If the PE is overdue, a red dash symbol should be entered in the discrepancy block.

d. Review (Part IV, AFTO Form 244). The review segment of the form provides a means to document a quality control or supervisory review of the equipment forms.

e. Discrepancies (Part V, AFTO Form 244). This is the area that will tell you what, if anything, is wrong with a particular piece of equipment. It also provides you with a place to enter any discrepancies you discover while you are operating the equipment. In the block marked "date discovered," enter the date you found the discrepancy. The date must be a five-digit number in the order of day/month/year. For example, 14 August 1982 will appear as 14082. The block labeled "discovered by" should contain your first initial, last name, and grade in that order and in signature form (not printed). In the "symbol" block, enter one of the symbols discussed above (red X through red diagonal). This will require a judgement call on your part. If operating the equipment could be hazardous to the operator (a short circuit, for example) or damage the equipment or material, enter a red X. If the item can be used safely (such as an EN-52 printer with a loose brake knob), enter a red diagonal. If a PE is overdue, the symbol used is a red dash.

Once entered on a form, a red symbol cannot be erased or changed; it must be cleared and reentered. Always enter a discrepancy symbol as soon as the problem is discovered. A small discrepancy will become a serious problem if ignored. And a serious discrepancy can become a hazard if it goes unreported. NEVER fail to enter a red X just to keep the equipment "on line." Discrepancy symbols are always entered in red.

The form will have a block for the discrepancy itself. Enter a brief statement of what you have found wrong with the equipment. Entries such as "Number 3 rack drive chain loose" or "CRT inop" are usually sufficient. The last block to fill out is the job control number assigned to the problem by the maintenance section.

Since the directives governing the entries to be made on AFTO forms change from time to time, it is a good idea to check the latest edition of TO 00-20-7 for the actual form you are using and make sure there have not been any recent changes to these procedures.

Exercises (033):

From the following situations, write the discrepancy to be entered on the equipment maintenance form.

1. On 4 October 1983 Airman E. Donovan notices that the drive shaft in a Versamat processor is not moving properly.

2. Senior Airman Tom Mount is told to start up a Mark IV R5A printer on 22 September 1982. As he turns on the main power, he sees some wires arcing inside the cabinet.

3. On 13 June 1984 Sgt Jack Huntington notices that a titler he is about to use was due a PE on 10 June.

4. Amn Therese DeWitt is making prints on an SP 10/70B printer on 24 December 1982. She notices that the speed control knob is loose, although it still seems to be working.

034. Explain the procedures to be followed in reporting a discrepancy on a piece of equipment.

Reporting Discrepancies. After a discrepancy is found on an item of equipment, whether it is a malfunction of the equipment or an overdue inspection, you must take certain actions so that the condition can be corrected. Simply making entries on a form will do little good if no further action is taken.

The first item to remember is not an action to be taken, but rather one to avoid. Very simply stated it is this: do not attempt to make a repair which you are not qualified or equipped to make. There may be a few malfunctions which you can easily correct yourself, such as a burned out bulb in an EN-52 printer. Most problems, however, should be left to qualified maintenance technicians. As a rule of thumb, never try to make repairs which require repair authorization (another AFTO form), tools, or technical orders.

The first step you should take is to notify the maintenance section of the problem. Again, the procedure may vary from one operating unit to another. In a WS-430B, for example, the maintenance personnel are located within the same complex. At other organizations they may be a completely separate unit located across the base. In any case, the maintenance dispatcher or job controlman will need some information from you: the nomenclature and ID number of the equipment, the location of the equipment, your name and telephone extension, and a description of the discrepancy. If you have filled out the equipment maintenance form properly, all the information you need is at your fingertips.

Maintenance personnel will assign a job control number to your discrepancy. This number is used to control and identify maintenance jobs. Maintenance action is not authorized without a job control number assigned to the discrepancy. The job control number is a seven-digit number. The first three digits are the Julian date (without the year) of the day the problem was reported. For example, 20 February would be 051. The last four digits consist of a daily or monthly job sequence number. If yours is the third job received on 20 February, your job control number would be 0510003. Make certain you enter this number on the maintenance form you are using.

One final word: in many organizations it is common practice to identify "down" equipment with some sort of sign. This will prevent someone from being injured or the equipment from becoming damaged if it is accidentally turned on. If this practice is used in your shop, make certain you place the sign on the equipment.

Exercises (034):

1. What is the basic rule about operator repair of equipment?

2. Name three items of information necessary when notifying Maintenance of a discrepancy.

3. What would be the job control number for the sixth work order phoned in to Maintenance on 5 March 1984?

5-6. The Air Force Graduate Evaluation Program

There are several ways in which the Air Force evaluates training and graduates. For example, you, as a graduate or trainer, may be asked to complete a questionnaire, or you may be asked to complete one in your role of supervisor. It does not matter which hat you are wearing when you are asked to participate in the evaluation program; but, if you are a participant, you should do your evaluation conscientiously. Don't just fill in "satisfactory" blocks when you really mean "marginal." The evaluation questionnaires are a very valuable tool for the training activities. Without truthful and useful responses, the questionnaires are worthless.

035. State the purpose of the Air Force Graduate Evaluation Program and specify information used to evaluate it and why you should participate.

Scope of the Programs. In addition to the local evaluation of training, the Air Force also conducts training evaluation. This evaluation encompasses a much broader scope than just checking records, charts, and motivation. You may be required to participate in the Air Force Graduate Evaluation Program. Your participation may be as a graduate or as a supervisor of some other graduate. Therefore, the purpose of the program is to assess the training and the trainee. This assessment becomes a quality control device for Air Force training.

The evaluation program is a major aid in the control of formal and career development courses. The program provides information that is used to determine the:

a. Ability of the graduates to perform their assigned tasks to the level of proficiency specified in the applicable training standard.

b. Extent to which the graduates use acquired skills.

c. Extent to which the graduates retain knowledge gained from the training.

d. Need to revise the training standard or school.

e. Need for further evaluation of problem areas identified by the evaluation.

When all of these factors have been considered, the training standard and courses can be changed, updated, or certified as adequate. For example, suppose the basic imagery production school at Lowry AFB included instruction on motion picture camera operation. Through the graduate evaluation program, it is determined that graduates of the school do not operate this camera. The item in the STS could then be deleted and it would no longer be required instruction in the imagery production basic school or in the CDC.

Exercises (035):

1. What is the purpose of the Air Force Graduate Evaluation Program?

2. What information is used to evaluate the program?

3. Why is it important for you to participate actively in the USAF Graduate Evaluation Program?

036. Point out purposes and responsibilities related to field evaluation visits.

Methods. The three most commonly used methods of evaluating graduates are (1) field evaluation visits, (2) direct correspondence questionnaires, and (3) AF Form 1284, Training Quality Report (TQR). A fourth method, job performance evaluations, may be conducted if evaluation cannot be obtained by less costly means. Since this fourth method is seldom used because of its cost, we will not discuss it further.

Field evaluation visits. Personnel from the training activities, such as Lowry AFB, visit the using agency within 6 months after the graduates have been assigned. Evaluation personnel are usually training specialists and may be accompanied by career field specialists. The graduates, their supervisors, and others having a knowledge of the graduates' performance are interviewed. Information from the interviews is analyzed to see if the graduates are performing at the required proficiency. Analysis is applied also to the training standard and the course of instruction.

Field evaluation visits are the best method of gathering information from graduates and their supervisors. This is because of the face-to-face discussions and any confusion of questions can be cleared up immediately.

Direct correspondence questionnaires. A questionnaire is made from selected tasks taken from the training standard. The questions pertain to the skill and proficiency levels that graduates should have attained by attending the resident course. The questionnaires for resident course graduates are sent directly to the graduates and their supervisors within 6 months after graduation.

For graduates of correspondence courses, ECI has developed a questionnaire which is given to a sampling of CDC enrollees to complete. The ATC/ECI student survey is a brochure containing 26 survey questions and follows the last Volume Review Exercise of each course. The questionnaire also contains a statement alerting students to the fact that if a CDC contains outdated information or does not provide knowledge that the current Specialty Training Standard requires, they should contact their OJT supervisor and complete an AF Form 1284, Training Quality Report.

If responses on these questionnaires identify problem areas in the CDC, training activities will conduct followup evaluations to determine what actions are required to resolve these problems. For instance, if enough of our students indicated that the section on motion film processing was confusing, we (the authors) would rework the section and clarify it. Or, if most of the respondents indicated that this CDC was very well written and easily understood, we would spend at least 15 minutes patting ourselves on the back.

AF Form 1284 may be used by commanders, first sergeants, supervisors, trainers, and graduates throughout all commands. It provides feedback to ATC regarding the quality of basic military training and/or technical training.

An AF Form 1284 should be prepared if:

a. A graduate does not meet the proficency level or knowledge specified for a task in the training standard.

b. A graduate is not required to perform tasks listed in the STS while working in the assigned AFSC.

c. The STS code levels or tasks exceed the requirement of the graduate's AFSC.

d. Severe deficiencies in standards of conduct and discipline are observed that make the graduate ineffective in his or her job assignment.

Exercises (036):

1. Who usually conducts field evaluation visits?

2. Why are field evaluation visits the best method of evaluating graduates?

3. At what time might you be asked to complete a questionnaire?

4. Who may prepare an AF Form 1284?

Mathematics

MUCH OF THE photographic science is based on various types of measurements and computations. Since we are concerned with quantitative accuracy, you will find that most operations are best expressed in mathematical terms. You will be introduced to many scientific terms. Then these terms will be explored further and you will make statements about them. Such statements will be in the form of mathematical equations.

In your work as an imagery production technician, you are concerned with showing a conclusion from a set of scientific statements. The statements are something like the familiar "story" problem. You examine the story, convert it to an equation, and solve the equation. You must be aware that an understanding of mathematical procedures is necessary before you can solve your own story problem.

The purpose of this chapter is to strengthen your foundation of knowledges concerning exponents, logarithms, and algebra, upon which you can build solutions.

6-1. Weights and Measures

Throughout your career as a member of an imagery production laboratory, you are concerned with mathematical operations. These operations depend on the proper use of numbers. But what of the original input of numbers (quantities) to your mathematical system? Numbered values come from many sources. In compounding a chemical formula or making a chemical solution, you are concerned with weight and volume. You have certain number inputs and outputs when performing chemical analyses. You should notice that control charts require the entry of various computed values. Many other measurements and computations require utmost accuracy.

The numerical values you use are all expressed as specific units of measurement. These units usually are given in one of three systems—US customary, avoirdupois, or metric—and very often you may have to convert one value to another value in the same system or to convert from one system to another.

037. List the distinguishing characteristics of the two most common systems of weights and measures.

U.S. Customary System. This system of weights and measures is probably the one with which you are most familiar. A gallon of gasoline, an acre of land, a bushel of corn, a 12-foot length of lumber, etc., are most likely measures with which you are acquainted. Many conversions with this system are used so much that the factors are committed to memory. Examples such as 4 quarts to a gallon, 144 square inches to a square foot, etc., are all familiar. Other conversions are often forgotten from disuse such as 5 1/2 yards to 1 rod, 4 gills to 1 pint, etc.

In view of the large number of measures, and to refresh your memory, we have included table 6-1 as a reference. Note that sections covering the avoirdupois (weight measure) system and apothecaries' weight also have been added.

Metric System. The measure of length in the metric system is the *meter*. The length of the meter was at first determined as one ten-millionth part of the distance from the Equator to the North Pole. It was later found that there had been a slight error in its determination. At present, the length of a meter is considered to be equal to 1,650,763.73 wavelengths of the radiation produced by the Kr^{86} isotope of Krypton.

By an act established in July 1866, Congress fixed the relation of 1 meter = 39.37 inches. This is the only legal relation between the metric and the US customary systems, and it is used in this country for deriving the inch, foot, yard, etc., from the meter.

Exercises (037):

1. What are the two most common systems of weights and measures?

2. What is the measure of length in the metric system?

3. What is the official length of the meter?

4. What is the relation between the metric and US customary systems?

TABLE 6-1
WEIGHT AND MEASURES

6034

LINEAR MEASURE

12 inches (in) = 1 foot (ft)
3 feet = 1 yard (yd)
5½ yards = 1 rod (rd)
16½ feet = 1 rod
320 rods = 1 statute mile (mi)
5,280 feet = 1 statute mile
6,080 feet = 1 nautical mile (naut mi)
3 nautical miles = 1 nautical league (naut l)

WEIGHT MEASURE

27.3438 grains (gr) = 1 dram (dr)
16 drams = 1 ounce (oz)
7,000 grains = 1 pound (lb)
16 ounces = 1 pound
100 pounds = 1 hundredweight (cwt)
20 hundredweight = 1 ton (T)
2,000 pounds = 1 ton

SQUARE MEASURE

144 square inches (sq in) = 1 square foot (sq ft)
9 square feet = 1 square yard (sq yd)
30¼ square yards = 1 square rod (sq rd)
160 square rods = 1 acre (A)
640 acres = 1 square mile (sq mi)

LIQUID MEASURE

4 gills = 1 pint (pt)
2 pints = 1 quart (qt)
4 quarts = 1 gallon (gal)
31½ gallons = 1 barrel (bbl)
2 barrels = 1 hogshead (hhd)

CUBIC MEASURE

1,728 cubic inches (cu in) = 1 cubic foot (cu ft)
27 cubic feet = 1 cubic yard (cu yd)
128 cubic feet = 1 cord (cd)
16½-25 cubic feet = 1 perch (P)

DRY MEASURE

2 pints (pt) = 1 quart (qt)
8 quarts = 1 peck (pk)
4 pecks = 1 bushel (bu)

APOTHECARIES' WEIGHT

20 grains(gr) = 1 scruple (sc)
3 scruples = 1 dram (dr)
8 drams = 1 ounce (oz)
12 ounces = 1 pound (lb)

038. Use conversion tables to change given quantities from one measuring system to another.

System Conversions. The metric system was invented for simplicity, and it has been officially recognized and adapted in most countries. The simplicity of the metric system results from these facts: it is decimal and therefore fits our decimal notation; and its units for lengths, surfaces, solids, and weights are all dependent on one unit, the *meter*. In the US customary system of weights and measures, we have about 150 different terms and 50 different numbers. These numbers bear no relation to one another. In the metric system, we have a minimum number of different terms and but one single number—and that number is 10. Refer to table 6-2 for a breakdown of the terms used in the metric system.

The ability to use the metric system depends in great part on an understanding of the terms used. We think it is very

TABLE 6-2

THE METRIC SYSTEM

SIZE	POWER OF 10	PREFIX	SYMBOL	UNITS
Trillion	10^{12}	tera	T	
Billion	10^{9}	giga	G	
Million	10^{6}	mega	M	
Thousand	10^{3}	kilo	k	"meter" for length
Hundred	10^{2}	hecto	h	
Ten	10^{1}	deka	da	"gram" for weight
One	10^{0}			or mass.
Tenth	10^{-1}	deci	d	
Hundredth	10^{-2}	centi	c	"liter" for capacity
Thousandth	10^{-3}	milli	m	
Millionth	10^{-6}	micro	μ	"are" for area
Billionth	10^{-9}	nano	n	
Trillionth	10^{-12}	pico	p	

All prefixes above one are of Greek derivation; all below one are of Latin derivation.

The word "meter" is derived from the Latin "metrum" or the Greek "metron". Both mean "to measure".

The micro-meter is commonly called the micron.

The millimicron is equal to the nanometer.

important that you learn these terms and their meanings. For instance, the term "kilometer" should mean, at once, 1000 meters. On the other hand, the term "millimeter" should immediately mean one thousandth of a meter.

Conversion of one value in the metric system to another is quite simple, and this is probably its greatest advantage. This simplicity is due to the decimal relationship between the different terms. In changing to larger increments or denominations, we divide by 10, 100, 1000, etc., simply by moving the decimal point the correct number of spaces to the left. Thus, to change 3768 centimeters to meters, we divide by 100 simply by moving the decimal point two places to the left which gives us 37.68 meters. In a similar manner, 72.4689 grams becomes 0.0724689 of a kilogram. Conversions to any larger value in the metric system are done in a like manner.

In reducing to lesser increments, multiply by moving the decimal point to the right or by annexing ciphers. Thus, 25 meters becomes 2500 centimeters or 25,000 millimeters.

Changing from one system to the other is a matter of multiplication or division. For example, let's assume you want to change 13 meters to inches. First, go to a conversion table, such as shown in table 6-3, and you find that 1 meter equals 39.37 inches. Then multiply the 39.37 inches by 13, since you are concerned with 13 meters, and the answer is 511.81 inches. Going from inches to meters reverses the process, and division is used instead of multiplication. Other conversions are handled in a like manner.

Exercises (038):

Use table 6-3 to solve the following problems.

1. If the US adopted the metric system,

   a. What would the length of a football field (between goal lines) be in meters?

   b. What would be the dimensions in meters of a baseball park whose present dimensions are: left field - 322 feet, center field - 437 feet, and right field - 360 feet?

2. The distance between two towns is 17 miles. What is the distance in kilometers?

TABLE 6-3
CONVERSION FACTORS

6787

PHOTO DISTANCES

1 inch = 25.4 millimeters
0.001 inch = 0.0254 millimeters
0.001 inch = 25.4 microns
1 millimeter = 1,000 microns
1 centimeter = 10 millimeters
1 meter = 1,000 millimeters

GROUND DISTANCES

1 military pace = 2.5 feet
1 meter = 3.281 feet
1 kilometer = 0.6214 miles
1 mile = 5,280 feet
1 nautical mile = 6,080 feet
1 nautical mile = 1.15156 statute miles
1 mile = 8 furlongs
1 furlong = 10 chains
1 chain = 4 rods
1 rod = 16.5 feet

GROUND AREAS

1 acre = 43,560 square feet
1 square mile = 640 acres
1 square mile = 27, 878,400 square feet
1 square mile = 2.590 square kilometers
1 square mile = 259 hectares

ANGULAR MEASURES

60 seconds = 1 minute
60 minutes = 1 degree
360 degrees = 400 grads
1 grad = 0.9 degrees
1 grad = 54 minutes
1 grad = 100 centesimal minutes
1 centesimal minute = 100 centesimal seconds

METRIC WEIGHT

10 milligrams (mg) = 1 centigram (cg)
10 centigram = 1 decigram (dg)
10 decigrams = 1 gram (g)
10 grams = 1 decagram (Dg)
10 decagrams = 1 hectogram (Hg)
10 hectograms = 1 kilogram (kg)
1,000 Kilograms = 1 metric ton (T)

METRIC CONVERSION TABLE

1 meter = 39.37 inches = 3.28083 feet = 1.0936 yards
1 centimeter = .3937 inch
1 millimeter = .03937 inch = 1/25 inch (approximately)
1 kilometer = .62137 mile
1 foot = .3048 meter
1 inch = 2.54 centimeters = 25.4 millimeters

MISCELLANEOUS

1 cubic foot = 7.481 gallons
1 kilogram = 2.205 pounds
1 fathom = 6 feet
1 mile per hour = 1.467 feet per second
1 knot = 1.689 feet per second
Degrees Centigrade = 5/9 (Degrees Fahrenheit) −32
Degrees Fahrenheit = 9/5 (degrees Centigrade) +32

6-2. Basic Mathematics

In this section, we cover some of the more important basic mathematical principles and procedures that you will use. These are things that you studied before but you may have forgotten some of them. In these and subsequent studies, keep in mind that you should never attempt to solve a math problem as though it were a puzzle. There is no room for trial and error or guesswork. Before attempting a solution, you must first understand the problem. To do this you should carefully read and analyze the problem. If you cannot understand the problem, it is no use trying to solve it. Accuracy is of the utmost importance; a wrong answer has no value. You should check your work and apply some kind of proof, even if the check is only the application of common sense that tells you that the answer seems to be in error.

039. State the rule of precedence for performing mathematical operations.

Rule of Precedence. Before you begin your study, let's bring out one important point. In arithmetic, there are found fundamental operations: addition, subtraction, multiplication, and division. All other arithmetical operations are derived from or are a combination of these four. In a combination you must apply the *rule of precedence*. This rule establishes the order in which the operations must be performed. The order is as follows:

a. Multiply.
b. Divide.
c. Add.
d. Subtract.

Exercises (039):

1. List the order in which mathematical problems involving more than one operation must be solved.

040. State the rules for determining significant figures and rounding off quantities.

Significant Figures. When you are making computations, you are concerned with either exact or approximate numbers. An exact amount occurs in counting, such as counting ten $1 bills in your wallet. But any measurements you make are approximations. Thus, it is often desirable to show results as being accurate to a certain number of decimal places. It is impossible to obtain a measurement (of such things as length, time, mass, etc.) which is *absolutely* correct. For example, you measure an object on an aerial photograph and find that it is 4.7 inches in length. This means that you measured it to the nearest tenth of an inch. Its true length lies somewhere between 4.65 and 4.75 inches. The value of 4.7 inches represents two *significant* figures. A value of 4.653 represents four significant figures if the length of the object is measured accurately to the nearest hundredth. The last digit (3) is considered as an estimate and it may vary.

When we use the term "significant," we mean any figure that is reasonably accurate. Consider a 50-milliliter (ml) burette marked off in tenths of a milliliter. We can, with considerable accuracy, measure to tenths of a milliliter. But what about the in-between points? If you measure 22.65 ml, it means that 22.6 is an accurate figure and the 5 is an accurately *interpolated* figure, which is reasonably correct. Thus, 22.65 contains four significant figures.

Zeros often complicate the determination of the number of significant figures. A 22-ml measurement contains two significant figures. A 0.022-measurement still contains only two significant figures; the zero following the decimal point only serves to locate the decimal point. However, a value of 0.0220 contains three significant figures and a value of 0.02200 contains four. Using the same process, a value of 1.02200 has a total of six significant figures.

Another problem in determining significant figures occurs when zeros precede the decimal point. Consider an object such as a processing machine that weighs 1800 pounds. It would seem that we have four significant figures, but the two zeros *may* be included only to locate the decimal point. If this is the case, there are only two significant figures—the 1 and the 8. In a whole number such as this, the weight is accurate only to the nearest 100 pounds. If the weight were accurate to the nearest 10 pounds, the accuracy could be written in exponential form as 1.80×10^3 and we have four significant figures ($1.800 \times 1000 = 1800$).

Some rules to follow for determining significant figures are:

a Digits other than zero are always significant.

b. A zero between two other significant digits is always significant.

c. When a number is less than 1, the zero between the decimal point and the first nonzero digit are not significant, but any zeros after the last nonzero digit are significant.

d. When a number is equal to or greater than 1 and is written with a decimal point, all zeros to the right of the last nonzero digit are significant.

Rounding. Oftentimes when you are working with decimals a number of figures are combined, and each number will have a different number of significant figures. For ease of further computations, numbers are often "rounded off." Two general rules to follow are:

a. Do not keep more decimal places than occur in the number having the least number of significant figures during addition and subtraction.

b. Do not keep more significant figures than occur in the number having the least number of significant figures during multiplication and division.

When numbers are rounded off, it means that one or more digits on the right of the decimal point can be dropped. When the extreme right-hand digit is less than 5, the preceding digit that is kept is left unchanged. If the digit being dropped is more than 5, a value of 1 is added to the preceding digit. When the digit being dropped is 5, a value of 1 is added to the preceding digit if that digit is odd. When the last digit being kept is even and it is followed by a 5, the 5 is simply dropped and the digit preceding it is left unchanged. Following are some examples of rounding.

42.24258 to
42.2426 to
42.243 to
42.24 to
42.2 or
23.75 to 23.8
23.85 to 23.8
1.35 to 1.4
1.45 to 1.4

Exercises (040):

1. List the rules for determining the number of significant figures in a given quantity.

2. List the rules for rounding off quantities.

041. Solve mathematical problems involving ratio and proportion, powers of numbers, and roots of numbers.

Ratio and Proportion. A working knowledge in this area will make it easier for you to solve many problems associated with imagery production. Problems involving ratios and proportions will arise in the mixing of chemicals, changing to a specific scale during photographic reproduction, determining how many exposures can be made on a roll of film, etc. These are practical applications which you will expand upon during your experiences in this career field. Let's start by taking a more detailed look at ratios.

Ratios. The relation of one number to another number of the same kind, as indicated by division, is called the *ratio* of the first to the second. A ratio is usually expressed as a fraction such as 3/4. Sometimes the ratio is expressed with the terms separated by a colon, as 3:4 (3 is to 4).

The two numbers involved in a ratio are called the *terms of the ratio*. The dividend of the ratio is called the *antecedent*, and the divisor is called the *consequent*. In the ratio 1/3, the 1 is the antecedent, and the 3 is the consequent. If the 1/3 ratio is inverted, we obtain a ratio of 3/1, and it is considered the inverse. In the case of the 3/1 ratio, you will note that its value is greater than 1; thus it is called a *ratio of greater inequality*. If the ratio is less than 1, it is a *ratio of less inequality*.

There are some principles of a ratio that should be brought out at this time. These are as follows:

a. Both terms of a ratio may be multiplied, or both may be divided by the same number without changing the value of the ratio.

b. A ratio of greater inequality is diminished, and a ratio of less inequality is increased by adding the same number to both terms.

c. In a series of ratios, the sum of all antecedents is to the sum of all consequents as any antecedent is to its consequent.

d. Since a ratio is a fraction, the principles of fractions are true for all ratios.

In stating the relations between the magnitudes of numbers, you will notice that there are several expressions more or less in common use. The expressions "in the same ratio as," "in the same proportion," "proportionally," and "prorata" have much the same meaning.

When it is said that 20 items are divided between two people in the ratio of 2 to 3, it is meant that one person gets two of the items as often as the other person gets three. That is, of each five units, one gets two and the other gets three. Therefore, one gets 2/5 of 20, or 8; and the other gets 3/5 of 20, or 12.

Let us consider another example having a closer relationship to photography. Consider the light-stopping ability of a certain density in a sensitometric strip. The following example could apply:

$$T = \frac{It}{Ii}$$

where

T = transmittance
It = illuminance transmitted = 50 meter candles
Ii = incident illumination = 100 meter candles

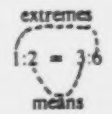
thus, $T = \frac{50}{100} = \frac{1}{2} = 0.50$, or 50 percent transmitted light:

Proportions. A proportion is a statement of the relationship between two or more ratios. Thus, if 1/2 = 3/6, the 1, 2, 3, and 6 are said to be in proportion, or form a proportion. A proportion such as this is often read 1 is to 2 as 3 is to 6, and it may be written in the following ways: 1 is to 2 = 3 is to 6, 1:2 as 3:6, or 1/2 = 3/6.

In a proportion, the first and fourth terms are called the *extremes*, and the second and third terms are called the *means*, as shown in the following examples.

$$\begin{matrix}\text{(Extreme)} \\ \text{(Mean)}\end{matrix}\ \frac{1}{2} = \frac{3}{6}\ \begin{matrix}\text{(mean)} \\ \text{(extreme)}\end{matrix}$$

or



A proportion is correct when equality is obtained by cross multiplication of the terms; in other words, the product of the means equals the product of the extremes. In solving any proportion problem, it is important to remember that any change in one term requires a change in the corresponding term on the other side of the equation. When you are setting up a proportion, keep like terms on the same side of the equation, using the smallest number as the numerator as in the following example:

$$\frac{9 \text{ inches}}{12 \text{ inches}} = \frac{6 \text{ feet}}{8 \text{ feet}}$$

Listed below are some of the important principles of proportion. Adherence to these principles will enable you to construct proportions.

a. If four numbers are in proportion, the product of the extremes is equal to the product of the means.

b. If the product of two numbers equals the product of two other numbers, either two may be made the means of a proportion, and the other two may be made the extremes.

c. The product of the means divided by either extreme equals the other extreme. The product of the extremes divided by either mean equals the other mean.

Now, let's examine some practical applications of a proportion. By studying the above principles, you see that when three factors in a proportion are known, you can readily solve the equation for the unknown fourth factor. Here is a problem in proportion: If 3 gallons of developer requires 6 ounces of sodium carbonate, how much sodium carbonate would be needed for 31 gallons of developer? This is solved in the following manner:

$$\frac{3 \text{ gallons}}{31 \text{ gallons}} = \frac{6 \text{ ounces}}{x \text{ ounces}}$$
$$3x = 186$$
$$x = 62 \text{ ounces of carbonate}$$

Here is another example of solving for an unknown in a proportion: If 90 exposures can be made on a 50-foot roll of film, how many exposures can be made on a 15-foot roll? Solve this in the following manner:

$$\frac{15 \text{ feet}}{50 \text{ feet}} = \frac{x \text{ exposures}}{90 \text{ exposures}}$$
$$50x = 1350$$
$$x = 27 \text{ exposures}$$

Here is an example where you must find a percentage: 45 is what percent of 75? At first glance it seems as though one term is missing. The missing term is 100 percent, and it is positioned in the proportion in the following manner: 45 is to x = 75:100. The problem is solved as follows:

$$\frac{45}{x} = \frac{75}{100}$$
$$75x = 4500$$
$$x = 60 \text{ percent}$$

and check as follows:

$$\frac{45}{60} = \frac{75}{100}$$
$$45 \times 100 = 75 \times 60$$
$$4500 = 4500$$

Before we leave this area, let's cover one more use of a proportion. Consider the horizontal distance between two points on an aerial photograph, and the same distance which can be measured on a map, whose scale is known. From experience, you know that the horizontal distances on the photograph and the map form a ratio. Using this information, a proportion can be set up to find the representative fraction (RF) of the photograph (or unknown fourth term) since you know the RF of the map.

Map measurement = 0.108 feet
Photo measurement = 0.432 feet
RF of the map = 1/50,000
RF of the photo = x

The proportion is set up as follows:

$$\frac{0.108}{0.432} = \frac{x}{50{,}000}$$
$$0.432x = 5400$$
$$x = 12{,}500$$

or

Photo RF = 1/12,500

Powers of Numbers. When we have several numbers multiplied together, as in 3 × 4 × 6 = 72, we call the numbers 3, 4, and 6 *factors*, and 72 is the *product*. If we make all the factors alike, as in 2 × 2 × 2 × 2 = 16, we call the product by a special name, *power*. We say that 16 is a power of 2, and 2 is the *base* of the power.

Considering the above, you can see that a power is a product obtained by using a base a certain number of times as a factor. If the base is used twice as a factor, the power is called the second power (or the number squared); three times as a factor, the third power; as in our example where we used four times as a factor, the fourth power; and so on for any number of times.

In order to show to what power a number is to be raised, a small number is written to the right and slightly above the number. This small figure is called the exponent. Thus, 3^3 reads three to the third power (or the number cubed), which in turn is 3 × 3 × 3 = 27. Any number may be multiplied by itself any number of times; thus, 9^2 means 9 × 9; and 5^4 means 5 × 5 × 5 × 5, etc. The use of exponents, such as in the above examples, gives us a short and concise way of writing a continued product when the factors are all alike.

You will use exponents time and time again. For example, they have considerable application in logarithmic computations. Also, exponents can be something other than the positive numbers we used in the previous examples. Consider the number 10 to the first power 10^1. This is 10. The number 10^2 equals 100. Now go in the negative direction and 10^{-1} equals 1/10 and 10^{-2} equals 1/100. Many times you will use exponents in problems similar to the following:

$$2.5 \times 10^2 = 250$$
$$2.5 \times 10^1 = 25$$
$$2.5 \times 10^{-1} = 0.25$$
$$2.5 \times 10^{-2} = 0.025$$

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Negative exponents are used more often than you might think. You may have seen them used as an expression of wavelengths; for example, in the statement that visible radiation wavelengths extend from about 4×10^{-5} centimeters to about 7×10^{-5} centimeters. Or, you may have seen maximum photographic detail size expressed as, for example, 3×10^{-4} centimeters in terms of a certain resolution of, say, 300 lines per millimeter. In many respects, either negative or positive exponents are a shorthand method of expressing very small fractions or very large numbers.

Roots of Numbers. If we separate a number, such as 16, into two equal factors of 4 and 4, that is $16 = 4 \times 4$, then one of these factors of 4 is called the *square root* of the number 16. Notice that this process is just the inverse of the process by which the power is found. In a similar manner, $125 = 5 \times 5 \times 5$, in which is called the cube root of 125.

The square root of a number is one of two equal factors into which a number is divided. If we multiply these factors, their product equals the number.

The cube root is one of three equal factors into which a number is divided, the fourth root is one of four equal factors, and so on for higher roots. In general, square root is the one with which you will be concerned most.

On many occasions it is necessary to extract a root of a number, especially the square root. Naturally, you can use the arithmetical procedure for this, but the simplest methods are to use a slide rule or a functions of numbers table.

Radical sign and root index. To indicate a root, the *radical* sign $\sqrt{}$ is used. A small figure, called the *index* of the root, is placed in the opening of the sign to show what root is to be taken. Thus, $\sqrt[3]{125}$ indicates the cube root of 125. The small number ^{3} is the *index of the root*. Since the square root is the root most frequently used, the index ^{2} is omitted. Thus, the square root of 400 is written as $\sqrt{400}$. Higher roots are indicated as $\sqrt[5]{1,000,000}$, $\sqrt[7]{12,800}$, etc. The process of finding the root of a number is called evolution and is commonly called extracting the square root of, extracting the cube root of, etc.

Perfect powers. The values of roots may be found by simple arithmetic or by reference to tables. Square roots are the ones most commonly used. The numbers 1, 4, 9 16, 25, 36, 49, 64, 81, 100, which are the squares of the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, should be remembered. It is apparent that these are the only numbers up to 100 of which we can find a whole number square root. Such numbers are called *perfect powers*.

The square root of 36 is 6, but the square root of 56 cannot be expressed as a whole number nor can it be expressed exactly as a decimal. Such numbers are called *imperfect powers*. Thus, 8 is a perfect third power whose cube root is 2; however, 8 is an imperfect second power, since its square root cannot be expressed exactly.

Operations involving radicals. Consider the significance of a fractional exponent. If you were to square the quantity $x^{1/2}$, you would have $(x^{1/2})(x^{1/2})$. By adding the exponents $x(^{1/2}) + (1/2)$ (multiplication), you will note that the result is x^1 or just x. By this reasoning, you will note that $x^{1/2}$ is the square root of x. In a like manner $x^{1/3}$ is the cube root ($\sqrt[3]{x}$) of x and $x^{1/4}$ is the fourth root ($\sqrt[4]{}$) of x. The expression $x^{1/3}$ is read as x to the two-thirds power. This means that x is raised to the power of the numerator of the fractional exponent and reduced by the root of the denominator. Thus $x^{2/3}$ is the cube root of x squared, or $\sqrt[3]{x}$.

To extract the square root of a common fraction, reduce it to its lowest terms and then extract the square root of the numerator and of the denominator. If both terms are not perfect squares, it is advisable first to reduce the common fraction to a decimal fraction and then to extract the square root.

You recall that we mentioned roots higher than square roots. Cube roots and higher are seldom used, and the process of extracting them by the arithmetical method is somewhat impractical. Therefore, at this point we need not discuss them. However, to find higher roots, there is a relatively simple method that involves the use of logarithms, which is discussed later in this chapter.

You may, at times, find that it is necessary to simplify an expression involving radicals without changing its value. This simplification procedure is advantageous only if the quantity under the radical sign (called radicand) can be divided into two factors, with one of these being a perfect power. Consider the following examples:

a. $\sqrt{81}$. Simplification is not needed here since 81 is a perfect power; that is, $9 \times 9 = 81$. Therefore, $\sqrt{81} = 9$.

b. $\sqrt{65}$. Simplification would not help in this type problem. This example can be simplified to $\sqrt{5 \times 13}$, but neither factor is a perfect power. Therefore, no quantity can be taken out of the radical.

c. $\sqrt{80}$. Simplification would be beneficial in this type expression. It can be simplified to $\sqrt{16 \times 5}$. 16 is a perfect power ($4 \times 4 = \sqrt{16}$). Therefore, $\sqrt{80} = \sqrt{16 \times 5} = 4\sqrt{5}$. Another example is $\sqrt{54} = \sqrt{9 \times 6} = 3\sqrt{6}$.

If a root other than the square root is already indicated such as $\sqrt[3]{16x}$, the simplified expression must contain a perfect third power factor. In this case, $\sqrt[3]{16x} = \sqrt[3]{8 \times 2x}$ (8 is an imperfect second power, but a perfect third power; $2 \times 2 \times 2 = 8$) $= 2\sqrt[3]{2x}$.

When the quantity under the radical sign is a fraction, multiply both the numerator and the denominator by a quantity which will make it possible to take the indicated root of the denominator. An example of this procedure is shown below:

$$\sqrt{2/3} = \sqrt{2/3 \times 3/3} = \sqrt{6/9} = \sqrt{1/9 \times 6} = 1/3\sqrt{6}$$

Using the above method, it is possible to carry the procedure even further by finding the square root of 6 (2.449) from a table of squares and square roots or by mathematical computation. The figure of 2.449 is then multiplied by 1/3, giving a result of 0.8163.

You may combine (add or subtract) radicals if they differ only in the coefficient; that is, if they have the same radicand and root. This procedure is shown in the following examples:

$$4\sqrt{x} + 3\sqrt{x} - 2\sqrt{x} = 5\sqrt{x}$$
$$\sqrt{4x} + 5\sqrt{x} = 2\sqrt{x} + 5\sqrt{x} = 7\sqrt{x}$$

Two radicals may also be multiplied if they have the same indicated root. You can do this by multiplying the coefficients together to obtain the coefficient of the product and by multiplying the radicands to obtain the radicand of the product. The following examples illustrate the multiplication procedure:

$$(2\sqrt{3})\ (3\sqrt{2}) = 6\sqrt{6}$$

$$(7\sqrt{x})\ (2\sqrt{y}) = 14\sqrt{xy}$$

$$(2\sqrt{x})\ (3\sqrt{x}) = 6\sqrt{x^2} = 6x$$

$$a\sqrt{b}\ (2\sqrt{3}+4) = 2a\sqrt{3b} + 4a\sqrt{b}$$

$$(5\sqrt{3} + 2\sqrt{6})\quad (5\sqrt{3} + 4\sqrt{6})$$

$$\begin{array}{r} 5\sqrt{3} + 2\sqrt{6} \\ \underline{5\sqrt{3} + 4\sqrt{6}} \\ 25\sqrt{9} + 10\sqrt{18} \qquad\qquad \\ \underline{20\sqrt{18} + 8\sqrt{36}} \\ 25\sqrt{9} + 30\sqrt{18} + 8\sqrt{36} \end{array}$$

Reducing,

$$25 \times 3 + 3\sqrt{9 \times 2} + 8 \times 6 = 75 + 30$$
$$\times\ 3\sqrt{2} + 48 = 123 + 90\sqrt{2}$$

Since radicals can be multiplied, it follows that they can also be divided. To accomplish this, reverse the multiplication procedure; that is, divide coefficient by coefficient and radicand by radicand. In many cases, the result of this process is an expression with a radical in the denominator. The radical can be eliminated by changing the denominator to a whole number, a fraction, or a mixed number. This process is called *rationalizing the denominator*, and for monomials it is the same process previously discussed as the "simplification of fractional radicands." The following example illustrates the process:

$$\frac{\sqrt{5}}{\sqrt{6}} = \sqrt{\frac{5}{6}} = \sqrt{\frac{5}{6}} \times \frac{6}{6} = \sqrt{\frac{30}{36}}$$
$$= \sqrt{\frac{1}{36}} \times 30 = 1/6\sqrt{30}$$

When the denominator is a binomial, rationalize by multiplying both the numerator and denominator by the binomial but with the sign between terms changed. This changed binomial is called the *conjugate of the denominator*. The process is as follows:

$$\frac{5}{3-\sqrt{2}} = \frac{5}{3-\sqrt{2}} \times \frac{3+\sqrt{2}}{3+\sqrt{2}} = \frac{15+5\sqrt{2}}{9-\sqrt{4}}$$
$$= \frac{15+5\sqrt{2}}{9-2} = \frac{15+5\sqrt{2}}{7}$$

$$\frac{x}{\sqrt{x}+y} = \frac{x}{\sqrt{x}+y} \times \frac{\sqrt{x}-y}{\sqrt{x}-y} = \frac{x\sqrt{x}-xy}{\sqrt{x^2}-y^2}$$
$$= \frac{x\sqrt{x}-xy}{x-y^2}$$

$$\frac{4-\sqrt{x}}{2+\sqrt{x}} = \frac{4-\sqrt{x}}{2+\sqrt{x}} \times \frac{2-\sqrt{x}}{2-\sqrt{x}}$$
$$= \frac{8-6\sqrt{x}+\sqrt{x^2}}{4-\sqrt{x^2}} = \frac{8-6\sqrt{x}+x}{4-x}$$

Exercises (041):

1. Solve the following ratio and proportion problems. (NOTE: Since scale denominators only are used, their positions are inverted in the ratio.)

   a. 3:7::6:x

   b. 9:11::x:17

   c. 2:5::7:x

   d. x:3::9:18

   e. 6:x::2:3

2. If 4 liters of developer required 12.5 grams of potassium bromide, how much potassium bromide would be required for the following quantities of developer?

   a. 17 liters.

   b. 26.5 liters.

   c. 35 liters.

   d. 61 liters.

   e. 89 liters.

3. If 15 feet of film is needed to record 27 exposures, how many feet will be needed to record the following number of exposures?

   a. 19.

   b. 101.

   c. 83.

   d. 276.

   e. 169.

4. To what power must each value in column A be raised to equal the corresponding quantity in column B?

	Column A	*Column B*
a.	3	27
b.	5	625
c.	2	64
d.	4	256
e.	6	216

5. Raise the following numbers to the powers indicated.

   a. 6^3

   b. 13^4

   c. 63^2

   d. 41^3

   e. 19^4

6. Simplify the following expressions.

   a. $\sqrt{48}$

   b. $\sqrt{245}$

   c. $\sqrt{108}$

   d. $\sqrt{175}$

   e. $\sqrt{192}$

042. Solve mathematical problems involving signed numbers.

Fundamentals of Algebra. In mathematics, an attempt is always made to do various calculations by an easier process. In arithmetic you learned to multiply 9 × 10 rather than adding a column of 10s. You simplified the job. Algebra is also a kind of work simplification, though at times it may not seem so. For example: consider the problem of what unknown number times 8 plus 12 equals 44? Arithmetically, this takes a bit of thought and the probable application of much trial and error. But in algebra we can easily evolve and solve an equation as follows:

$$\begin{aligned} x \text{ times } 8 \text{ plus } 12 &= 44 \\ 8x \text{ plus } 12 &= 44 \\ 8x &= 44 - 12 \\ 8x &= 32 \\ x &= 4 \end{aligned}$$

so,

$$4 \times 8 + 12 = 44$$

Algebra is that part of math that employs letters in reasoning about numbers; either to find their general properties or to find the value of an unknown from its relation to known numbers such as we just did. This was a simple example but it served to illustrate the point.

In your previous studies, you learned much about mathematics in general. It is our purpose here to review some of the algebraic operations and principles you probably already know and build upon this knowledge.

Rules of precedences. We mentioned this rule earlier in the chapter. The rule still holds in algebra. Operations must be performed in the following order:

a. Multiply.
b. Divide.
c. Add.
d. Subtract.

In some instances you may have to modify the rule when grouping symbols such as parentheses, brackets, and braces are used. These markings (along with the rule of precedence when appropriate) indicate the first order of operation. The operation enclosed within the innermost group is performed first. Following is a simplified example:

$$\begin{array}{l}
5x + \{3x - [2x + (3x + 5x)]\} - x \\
5x + \{3x - [2x + 8x]\} - x \\
5x + \{3x - 10x\} - x \\
5x - 7x - x \\
5x - 8x \\
-3x
\end{array}$$

The rules for the introduction of grouping signs follow the rules for removal. Any number of terms of an expression may be placed within a sign of grouping which is preceded by a plus sign without changing the sign of any term within the group. Also, any number of terms of an expression may be placed within a sign of grouping preceded with a minus sign by changing the sign of every term within the group. It is customary to prefix the sign of grouping with the sign of the first term that is to be enclosed within it. Now, before we go any deeper, let's examine some of the words we will use in this study as the above-mentioned *terms* and *expressions*.

Definitions. Partly to refresh your memory and partly to eliminate confusion, let us review some of the word definitions appropriate to algebra—the language of mathematics. Following are some of the more common definitions:

Term. The term is a letter or number, or a group of letters or numbers, not separated by a plus or minus sign. The combination of $-3x^2$ is an example of an algebraic term.

Sign. The sign of a number is the direction of the number with respect to zero. In the preceding term, the sign is negative.

Numerical coefficient. This is the numerical part of the term. In $-3x^2$, the numerical coefficient is 3.

Literal part. The literal part of $-3x^2$ is the x. The numerical coefficient and the literal part must be joined by an indicated multiplication or division.

Exponent. The exponent is the power of the number. The exponent in the term $-3x^2$ is the number 2. If the exponent is omitted, it is understood to be 1.

Like terms. These are terms which have identical literal parts and exponents.

Expression. Any combination of numbers or letters representing numbers is called an expression. An algebraic expression consists of one or more terms. If the expression has one term, it is called a *monomial*. If it has more than one term, it is usually called a *polynomial*. Polynomials are also called compound expressions. Also, the terms, "binomial" and "trinomial" are applied to expressions with two and three terms respectively.

At this point, let's do some work with algebraic terms and expressions. We will start with addition and then cover subtraction, multiplication, and division.

Addition. An algebraic number which is added to another or multiplied, subtracted, or divided is often encased in parentheses ( ). This is done so that the signs + and −, which are often used to distinguish positive and negative numbers, are not confused with the + and − signs that denote the operations of addition and subtraction. For example, add a +4 and a −3. Using parentheses, this would be set up as follows: $(+4) + (-3) = +1$.

To add numbers with *like* signs, simply find the arithmetical sum. If you add a positive (+) 32.1 and a +16.8 the sum is a +48.9. Both signs are +; therefore, the sum takes the common sign of +. If you add a −32.1 and a −16.8 the common sign is minus (−), and the sum is a −48.9. Notice that the common (−) sign is used in this summation.

To add numbers with *unlike* signs, subtract the smaller number from the larger number and place the sign of the larger before the answer.

If a series of numbers with unlike signs are to be added, the procedure is similar to the above. First, find the sum of all the positive numbers; then find the sum of all the negative numbers; finally, find the difference of the two sums, and prefix the sign of the larger sum.

At this point, let us expand our terms and include some letters. If you add 3a, 5a, 2a, 6a, and a, simply add the coefficients and obtain 17. Prefix the common sign which is plus, annex the literal part (letter), and the sum becomes +17a.

Now, try adding the above series of terms if they have signs as follows: −3a, +5a, −2a, +6a, and −a. Addition of these terms is shown below.

$$\begin{array}{r} -3a \\ -2a \\ \underline{-a} \\ -6a \end{array} \qquad\qquad \begin{array}{r} +5a \\ \underline{+6a} \\ +11a \end{array}$$

$$\begin{array}{r} +11a \\ \underline{-6a} \\ +5a \end{array}$$

Many times in algebra you may be required to add several terms which are not all alike. If you add a number or polynomials, note that it is convenient to arrange the terms in columns so that like terms all stand in the same column.

$$\begin{array}{rrrr}
2a^3 & -\,3a^2b & +\,4ab^2 & +\,b^3 \\
a^3 & +\,4a^2b & -\,7ab^2 & -\,2b^3 \\
-3a^3 & +\,a^2b & -\,3ab^2 & -\,4b^3 \\
2a^3 & +\,2a^2b & +\,6ab^2 & -\,3b^3 \\
\hline
2a^3 & +\,4a^2b & & -\,8b^3
\end{array}$$

In the above example, we cannot combine unlike terms. In everyday life, unlike objects cannot be added or subtracted. So it is with algebraic terms. Apples can be neither subtracted from nor added to bananas; likewise, the term "2a" cannot be subtracted from, or added to, 3b.

Subtraction. We know, from working with positive numbers, that subtraction is the inverse of addition. If we are given one of two numbers and their sum, subtraction is the process of finding the other number. It is assumed that the minuend may be negative numbers.

Since subtraction is the inverse of addition, you should remember the following principles.

a. Subtracting a positive number is equivalent to adding a numerically equal negative number.

b. Subtracting a negative number is equivalent to adding a numerically equal positive number.

c. you use these two principles, you should not be confused about signs.

To subtract one algebraic term from another, proceed as shown in the following example: Subtract:

$$\begin{array}{l}
mn - xy \text{ from } ab + cd \\
(ab + cd) - (mn - xy) \\
(ab + cd) + (-mn + xy) \\
ab + cd - mn + xy
\end{array}$$

Just as in addition, where we combine polynomials, we may also subtract polynomials. A typical procedure is shown in the following example:

Subtract:

$2x^3 - x^2y + 5xy^2 - 3y^3$ from $4x^3 - 3x^2y - xy^2 + 2y^3$

Add:

$$\begin{array}{rl}
4x^3 - 3x^2y - xy^2 + 2y^3 & \text{(minuend)} \\
-2x^3 + x^2y - 5xy^2 + 3y^3 & \text{(subtrahend with sign changed)} \\
\hline
2x^3 - 2x^2y - 6xy^2 + 5y^3 &
\end{array}$$

Multiplication. In the multiplication of algebraic terms there are three things you must consider—the sign, the coefficient, and the exponent. Let us discuss these three separately. As in subtraction, the problem in multiplication is largely the application of the correct sign. The multiplier means "so many times." A multiplicand can be either positive or negative, but the multiplier, when integral, means that the multiplicand is taken so many times to be added or subtracted. An integral multiplier with the plus (+) sign means that the multiplicand is taken so many times to be *added*. If the multiplier has the minus (−) sign, it means that the multiplicand is taken so many times to be *subtracted*. Use of this reasoning allows us to make up some rules of signing in multiplication as follows:

$$\begin{array}{l}
+ \text{ times } + = + \\
- \text{ times } - = + \\
+ \text{ times } - = - \\
- \text{ times } + = -
\end{array}$$

To find the product of three or more signed numbers, find the product of the first two, prefix the proper sign, and multiply this product by the third number. Prefix the correct sign to the second product and continue until all of the multiplications have been made.

Now, let's see what you do when multiplying coefficients. As an example, multiply (2x) (−3y) (4z). This operation takes a form as follows:

$$2 \times -3 \times 4 = -24$$

and

$$(x)\,(y)\,(z) = xyz$$

therefore

$$(2x)\,(-3y)\,(4z) = -24xyz$$

Note that the literal factors of x, y, and z represent unknowns. Therefore, it is impossible to express them in any other way than xyz.

Terms to be multiplied often include exponents. Using only numbers, $10^2 \times 10 = 1000$. The answer could also be written as 10^3. In this case, you take the value of 10, *add* the exponents (2 + 1), and get 10^3. Numbers are usually multiplied out, hence the conventional 1000 as shown above. When working with literal factors (letters), the exponential handling is the same as above—you multiply exponents by adding them. Stated in another way, the exponent of any letter in the product is the sum of the exponents of the factors with the same base. For example:

$$(x^2)\,(x^3) = x^{(2+3)}, \text{ or } x^5$$

and

$$(y^5)\,(y^7) = y^{12}$$

Combining the various principles of signs, coefficients, and exponents we have covered, observe the treatment of the following multiplications:

$$\begin{array}{r}
(3a^2)\,(5a^2) = 15a^4 \\
(2ax)\,(-3a^2xy) = -6a^3x^2y \\
(m^2n)\,(-7mn^2) = -7m^3n^3 \\
(4xy)\,(-xy^2) = -4x^2y^3 \\
(-a)\,(-5a^2) = 5a^3
\end{array}$$

Notice in the above that a literal quantity with no written exponent means that the quantity has an exponent of 1. To fix multiplication in your mind, let's take one more example before we multiply a polynomial by a monomial:

$$14a^4b^3 \times -3a^3b^2 = 14 \times -3 \times a^4b^3 \times a^3b^2$$
$$= -42 \times a^7b^5 = -42a^7b^5$$

In the previous example, a sequence of operations was followed and should always be followed in similar multiplication problems. The sequence is as follows:

a. Sign of the product is + × − = −.
b. Coefficient of the product is 14 × 3 = 42.
c. Letters of the product are a and b.
d. Exponents of the letters are: for a, 3 + 4 = 7; for b, 2 + 3 = 5.

Polynomials by monomials. The procedure for this process is simply an expansion of the previous techniques. For greater ease in computation, the following problem is set up in an arithmetical format.

$$\begin{array}{l} 7ax^3 - 6ab^4 - 3x^2 \\ \underline{2a^4b^2x^4} \\ \hline 14a^5b^2x^7 - 12a^5b^6x^4 - 6a^4b^2x^6 \end{array}$$

Polynomials by polynomials. Further expansion of algebraic multiplication brings us to the multiplication of polynomials. After rearranging the terms, we must follow the method summed up in the following three operations.

(1) Multiply every term of the multiplicand by each term of the multiplier.
(2) Write the like terms of the partial products under each other.
(3) Find the algebraic sum of the partial products.

Using the previously learned principles of multiplication and the above three operations, follow the example shown.

$$(4x + 3 + 5x^2 - 6x^3)\,(4 - 6x^2 - 5x)$$

Rearrange terms:

$$\begin{array}{llllll} 3 & +\,4x & +\,5x^2 & -\,6x^3 & & \\ 4 & -\,5x & -\,6x^2 & & & \\ \hline 12 & +\,16x & +\,20x^2 & -\,24x^3 & & \\ & -\,15x & -\,20x^2 & -\,25x^3 & +\,30x^4 & \\ & & -\,18x^2 & -\,24x^3 & -\,30x^4 & +\,36x^5 \\ \hline 12\,+ & \;\;x & -\,18x^2 & -\,73x^3 & & +\,36x^5 \quad \text{(ans)} \end{array}$$

Division. If a product and one of its factors are given, the other factor may be determined by means of division. With reference to this operation, the product is called the dividend; the given factor is the divisor; and the required factor is the quotient. Since we are concerned with algebraic division, we must also be concerned with the proper signs throughout the operation. Division is the inverse of multiplication; therefore, signs are affixed as follows:

$$(+15) \div (+3) = +5 \text{ or } + \div + = +$$
$$(-15) \div (+3) = -5 \text{ or } - \div + = -$$
$$(-15) \div (-3) = +5 \text{ or } - \div - = +$$
$$(+15) \div (-3) = -5 \text{ or } + \div - = -$$

When exponents are to be considered in division, we again think of the inverse of multiplication. For example, if $a^2 \times a^3 = a^5$, then $a^5 \div a^3 = a^2$, or $-21x^6y^4 \div 7x^2y = -3x^4y^3$—exponents are subtracted. Generally speaking, when performing algebraic division, the problem is usually expressed in fractional form such as $\frac{48a^3b^2c}{4abc} = 12a^2b$.

To further illustrate the preceding problem, let us break the terms into their factors and do some cancellation. The quotient then results from a combination of remaining factors. In this case we use a dot (•) to indicate multiplication.

$$\frac{48a^3b^2c}{4abc} = \frac{\cancel{4} \cdot 4 \cdot 3 \cdot \cancel{a} \cdot a \cdot a \cdot \cancel{b} \cdot b \cdot \cancel{c}}{\cancel{4} \cdot \cancel{a} \cdot \cancel{b} \cdot \cancel{c}} = (4 \cdot 3)$$
$$\times (a \cdot a) \times (b) = 12a^2b$$

As in arithmetic, there are problems that require you to divide fractions. To divide fractions in algebra, invert the second fraction and multiply. This procedure is shown in the following examples:

$$\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \times \frac{d}{c} = \frac{ad}{bc}$$

and

$$\frac{a^3}{12b^2} \div \frac{a}{4b^3} = \frac{a^3}{12b^2} \times \frac{4b^3}{a} = \frac{\overset{a^2}{\cancel{a^3}}}{\underset{3}{\cancel{12b^2}}} \times \frac{\overset{b}{\cancel{4b^3}}}{\cancel{a}} = \frac{a^2b}{3}$$

The above procedures are considered the division of monomials. Now, let's consider the technique used to divide a polynomial by a monomial.

Polynomial by a monomial. The division of a polynomial by a monomial may be likened to short division in arithmetic. To accomplish the division, divide each term of the dividend by the divisor and add the partial quotients as indicated in the next example.

$$\frac{35p^4m + 75p^2m^3}{5p^2m} = 7p^2 + 15m^2$$

Notice the handling of exponents in the preceding example. If you prefer, a problem such as this can be set up and solved in an arithmetical format as shown in the next example. Again, note the handling of exponents and signs:

$$\begin{array}{rl} & \underline{x^2 - 4x + 3} \\ 2x \,/ & 2x^3 - 8x^2 + 6x \\ & \underline{2x^3} \\ & \quad\; - 8x^2 \\ & \quad\; \underline{- 8x^2} \\ & \qquad\qquad 6x \\ & \qquad\qquad \underline{6x} \end{array}$$

Polynomial by a polynomial. This division process bears certain similarities to long division. The work is performed readily if the following steps are followed carefully.

(1) Arrange both dividend and divisor in ascending or descending powers of some common letter.

(2) Divide the first term of the dividend and write the result for the first term of the quotient.

(3) Multiply the entire divisor by the first term of the quotient and subtract the result from the dividend.

(4) If there is a remainder, consider it a new dividend and proceed as before.

Keeping the above steps in mind, let us start with a simple division problem. Be sure you note the changes in sign when performing the subtractions:

$$\begin{array}{r} -3a + 6 \\ 2a + 3\ \overline{)\,-6a^2 + 3a + 18} \\ \underline{-6a^2 - 9a\qquad} \\ 12a + 18 \\ \underline{12a + 18} \end{array}$$

In the above example there is no remainder. Now, let's take an example where there is one:

$$\begin{array}{r} 10c^2 - 3c - 12 \\ 3c^2 + 2c - 4\ \overline{)\,30c^4 + 11c^3 - 82c^2 - 5c + 3} \\ \underline{30c^4 + 20c^3 - 40c^2\qquad\qquad} \\ -9c^3 - 42c^2 - 5c\qquad \\ \underline{-9c^3 - 6c^2 + 12c\qquad} \\ -36c^2 - 17c + 3 \\ \underline{-36c^2 - 24c + 48} \\ 7c - 45 \end{array}$$

NOTE: The answer to this problem can be in the form used in arithmetic as follows:

$$10c^2 - 3c - 12 + \frac{7c - 45}{3c^2 + 2c - 4}$$

Exercises (042):

1. Solve the following addition problems.

a. $\begin{array}{r} -6a - 13b \\ \underline{9a - 3b} \end{array}$

b. $\begin{array}{r} a + b \\ \underline{-2a - 5b} \end{array}$

c. $\begin{array}{r} 3x + 7y - 2z \\ \underline{-4x + y + 8z} \end{array}$

d. $\begin{array}{r} 4a - 5b + 2c \\ \underline{a + 3b - 2c} \end{array}$

e. $\begin{array}{r} 8a - 13b + c + 4d \\ -2a + 7b - 5c - 3d \\ \underline{-10a + 6b + 9c - 2d} \end{array}$

f. $\begin{array}{r} 3w + x - 2y + 2z \\ -4w + 7x + 8y + 3z \\ \underline{2w - x - 16y - 11z} \end{array}$

2. Solve the following algebraic subtraction problems.

a. $\begin{array}{r} 5x + y \\ \underline{4x - 3y} \end{array}$

b. $\begin{array}{r} 16a - 9b \\ \underline{-4a - 8b} \end{array}$

c. $\begin{array}{r} 6m + 4n \\ \underline{5m + 3n} \end{array}$

d. $\begin{array}{r} 9a - 5b + 7c \\ \underline{-a - 7b + 10c} \end{array}$

e. $\begin{array}{r} 3a + b - 2c + 2d \\ \underline{-11a + 7b - 3c - 7d} \end{array}$

f. $\begin{array}{r} 8w - 13x + y + 4z \\ \underline{4w - 7x - 8y + 3z} \end{array}$

3. Solve the following algebraic multiplication problems.

a. $\begin{array}{r} 3a + 4b \\ \underline{-2a} \end{array}$

b. $\begin{array}{r} 4a - 2b + 3c \\ \underline{3a} \end{array}$

c. $\begin{array}{r} 5x - y \\ \underline{2x + 3y} \end{array}$

d. $\begin{array}{r} x + xy - y \\ \underline{-y - y} \end{array}$

e. $\begin{array}{r} 3x + 7y - 2z \\ \underline{x + 3y - 2z} \end{array}$

4. Solve the following algebraic division problems.

a. $x + y\ \sqrt{x^2 - y^2}$

b. $3ab + 2b\ \sqrt{3a^2b + 2ab - 3ab^2 - 2b^2}$

c. $2a + 3b\ \sqrt{4a^2 + 12ab + 9b^2}$

d. $2x + 3y\ \sqrt{-4x^2 - 10xy - 6y^2}$

e. $a + b + c\ \sqrt{a^2 + 2ab + 2ac + b^2 + 2bc + c^2}$

6-3. Common Logarithms

The first impression many people have about logarithms (logs) is that they are complicated. But with a minimum of application, you should find that they are relatively simple and extremely useful in many of your computations. Even if you have studied them before, through disuse you may have forgotten the procedures. Therefore, some of the material presented here may be a review while other material may be new.

An understanding of logs is especially valuable in a study of sensitometry-densitometry where many values are expressed in logarithmic terms. Also, sensitometric curves are constructed using log values as a basis. For example, sensitometric curves plot the log of exposure against the log of opacity (density). This is a convenient way of making a long curve fit a short piece of paper. Now, let's take a closer look at logs, their parts, and the way they are computed.

043. List the procedures for determining the logarithm and antilogarithm for given values.

Logarithm Defined. The use of logarithms presents a convenient method for performing arithmetical calculations with ease and rapidity. Logarithms are *exponents*, or powers of 10, and the rules for the combination of exponents hold for them. Therefore, calculations involving the operations of multiplication, division, raising to powers, and extraction of roots can be performed with a sufficient degree of accuracy and with little effort.

The following operations show you how the use of logarithms simplifies many calculations:

- Multiplication is reduced to addition.
- Division is reduced to subtraction.
- Raising to a power is reduced to one multiplication.
- Extracting a root is reduced to a single division.

The logarithm of a quantity is the exponent, or the power, to which a given number, called the *base*, must be raised to equal that quantity. To illustrate, in the quantity $3^2 = 9$, the exponent 2 is called the logarithm of 9 to the base 3. This relation is usually written $\log 3^9 = 2$. Any positive number greater than 1 might serve as a base. Two numbers have been selected, resulting in two systems of logarithms. One base, 2.718, usually indicated by the Greek letter *epsilon* (E), is used in the system of *natural* logarithms. The other base is 10; it is used in the system of *common* logarithms. In the system of common logarithms, the base 10 is usually omitted in the logarithmic expression. Thus, $\log_{10} 1000 = 3$ is usually written $\log 1000 = 3$.

In the common system, logarithms that are exact powers of 10 are integers.

Thus,

$\log 10000 = 4$, since $10^4 = 10000$
$\log 1000 = 3$, since $10^3 = 1000$
$\log 100 = 2$, since $10^2 = 100$
$\log 10 = 1$, since $10^1 = 10$
$\log 1 = 0$, since $10^0 = 1$
$\log 0.1 = -1$, since $10^{-1} = 0.1$
$\log 0.01 = -2$, since $10^{-2} = 0.01$

For numbers that are not exact powers of 10, the logarithm consists of two parts, an integral part (whole number) and a decimal part. The log of 100 is 2 and the log of 1000 is 3. Thus, the log of 595 is somewhere in between 2 and 3 (2.7745). In logarithmic terminology, the 2 of the 2.7745 is called the *characteristic* and the .7745 is called the *mantissa*. Now, let's see how the characteristic is determined.

Characteristics. You can determine the characteristic by the following rules:

a. The characteristic of the logarithm of a number greater than 1 is positive and is one less than the number of digits to the left of the decimal point. For example, in the case of log 595, the characteristic is 2; and for the log of 59.5, the characteristic is 1.

b. The characteristic of the logarithm of a number less than 1 is negative and is equal to one more than the number of zeros immediately to the right of the decimal point. For example, for the log of 0.0595, the characteristic is −2, and for log 0.00595, the characteristic is −3.

When the characteristic is negative, do not put the minus sign in front of the logarithm, since it applies only to the characteristic and not the entire logarithm. Instead, add 10 to the negative characteristic and indicate the subtraction of 10 at the end of the logarithm.

Thus the characteristic −2 is written 8. (mantissa) −10, and the characteristic −3 is written 7. (mantissa) −10.

Another method of indicating that the characteristic is negative is to place the minus sign above the characteristic (commonly called bar characteristic). For example: $\overline{2}$. (mantissa) and $\overline{3}$. (mantissa). As you have seen, the characteristic is easily found. Finding the mantissa is a bit more involved.

Mantissa. In our previous example we used the log of 595, which is 2.7745. You know how to find the characteristic. We said that the mantissa is .7745. How do you find it? The answer is that you find the mantissa in a table of logarithms. You will see how this is done in a moment. First, one important point. Numbers that have the same figures in the same order but differ only in the position of the decimal point have the same mantissa in their logarithms. For example, the mantissa of log 595 is .7745 and the mantissa of log 5.95 is also .7745. With this in mind, let's go through a procedure of finding the entire log of a number.

Finding the log of a number. Once again, let's work with the log of 595. The first thing you do is to find the characteristic. As you recall, the characteristic is one less than the number of digits to the left of the decimal point. Therefore, the characteristic is 2.

Next, find the mantissa from logarithmic tables. The mantissa of the number is independent of the position of the decimal point, so you can disregard the decimal point in the number when finding the mantissa. The mantissas in the table are the decimal part of the logarithm and therefore should be preceded by the decimal point.

In four-place logarithms tables, as shown in figure 6-1, the first column in the table contains the first two digits of the numbers whose mantissas are given in the table, and the top row contains the third digit. Thus, to find the mantissa of 595, find 59 in the left-hand column and 5 at the top. In the column under 5, and opposite 59, is 7745, the mantissa. The logarithm of 595 is then 2.7745.

Here is something you may have wondered about. What if your number has more than three digits? To find the logarithm of a quantity with more than three digits, use the process called interpolation. Suppose you want to find the logarithm of 5956. Tables give the mantissas for 5950 and 5960. (The mantissa for 5950 is the same as that for 595. Likewise, the mantissa for 5960 is the same as that for 596.) Since 5956 lies between 5950 and 5960, its mantissa must lie between the mantissas for these two numbers.

By arranging the mantissas in the following tubular form,

mantissa of 5960 = .7752
mantissa of 5956 = ?
mantissa of 5950 = .7745

you can see that 5956 is 6/10 of the way between 5950 and 5960. Obviously, the mantissa of 5956 must be 6/10 of the way between .7745 and .7752. Since the difference between the two is .0007 and since 6/10 of .0007 is .00042, add .00042 to .7745 (the mantissa of 5950). The result, .77492, is the mantissa of 5956. Therefore, the logarithm of 5956 = 3.77492.

Antilogarithms. So far we have discussed how the log of a number is found so that you can use logs to simplify your calculations. Now, assume that you have made these calculations and a log answer has been found. To be a meaningful value, the log must convert to its appropriate number. The number corresponding to a given logarithm is

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N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	1502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

Figure 6-1. Common logarithm table.

called the *antilogarithm*. This term is shortened to antilog. To find the antilog, you simply reverse the process you used in finding the log. Let us go through a couple of examples to illustrate how this is done.

As our first example, assume that your answer to a problem is log 1.8987. You must find the antilog of this number. Go to your log tables and locate the mantissa .8987. The number is in line with the number 79 under column 2. Thus, the number corresponding to the mantissa .8987 has the digits 792. Now, you must find the location of the decimal point. To do this, reverse the rule for finding the characteristic. Since the characteristic is 1, count two places to the right and place the decimal point after the 9. Thus, the antilog of 1.8987 is 79.2

Now, another example. Find the antilog of 2.4325. Note that the tables do not show a mantissa of .4325. Therefore, you must interpolate between the mantissas .4314 and .4330, which are shown in the table. These mantissas correspond to 270 and 271 respectively. The difference between .4314 and .4330 is .0016. The difference between .4325 (given mantissa) and the mantissa for 270 is .0011. Now, divide .0011 by characteristic is 2, the antilog of 2.4325 is 270.687.

Exercises (043):

1. How is the characteristic of a number determined?

2. How is the mantissa for a number found?

3. What procedures are used to determine the antilog of logarithms?

4. When is interpolation of logarithms necessary?

5. In a logarithmic division problem, the characteristic of the divisor is -4, and the characteristic of the dividend is $+4$. What will be the characteristic of the quotient?

044. Solve multiplication and division problems by using logarithms.

Computation With Logarithms. At this point, let's consider a few representative examples of the use of logs. These examples show how lengthy arithmetical computations can be simplified. Starting with multiplication, remember that logs are added, whereas the numbers are multiplied. Using logs is advantageous when you must multiply large numbers. Take the following example, 6952 times 437. To multiply these two quantities, *add* the logs and find the antilog of the result as shown below.

$$6952 \times 437 = \log 6952 + \log 437$$
$$\log 6952 = 3.8421$$

Add

$$\log 437 = \underline{2.6405}$$
$$6.4826$$
$$\text{antilog } 6.4826 = 3{,}038{,}000$$

In the above example, actual number multiplication would give a figure of 3,038,024. This indicates an error of 24 in over 3 million or 00.0008 of 1 percent. The error is due to the fact that four-place tables were used. Greater accuracy is obtained if five-place tables are used. Generally speaking, however, accuracy obtained with four-place tables is sufficient.

Let's see what you do when *dividing* large numbers. Using the figures of the preceding example, divide 6952 by 437. Division is accomplished by *subtracting* log 437 (2.6405) from log 6952 (3.8421), which equals 1.2016. Then the antilog of 1.2016 is 15.907.

Exercises (044):

1. Solve the following multiplication problems using logarithms. Use figure 6-1 for determining the mantissa. Express your answers in both logarithmic and antilogarithmic form.

   a. $342 \times 79 =$

   b. $9.37 \times 6.8 =$

   c. $10.9 \times 9 =$

   d. $2{,}300 \times 1{,}970 =$

2. Solve the following division problems using logarithms. Use figure 6-1 for determining the mantissa. Express your answers in both logarithmic and antilogarithmic form.

   a. 97 ÷ 15 =

   b. 12,400 ÷ 75 =

   c. 0.00897 ÷ 98 =

   d. 732 ÷ 423

Photographic Processing Interpretation Facility

DEPARTMENT OF DEFENSE commitments have expanded throughout the world, and because of this, Air Force personnel are deployed in worldwide mobility situations. Along with the personnel it is necessary to have equipment to fulfill our mission. This creates a need for a processing facility which can be moved as easily as the personnel that operate it.

7-1. Mission and Management

The Air Force equivalent of this type of facility is known as the WS-430B. This facility is utilized mainly by the Tactical Air Command (TAC) for aid in its tactical air operations in reconnaissance. The majority of the assignments within this career field will be to support the TAC mission, making this area one of great importance. Now let's look at the mission, management, and some specific responsibilities of key personnel in a typical WS-430B.

045. Describe the mission and management of the Photographic Processing and Interpretation Facility (PPIF), and specify qualifications and responsibilities of key personnel.

Mission. The WS-430B, also known as the Photographic Processing and Imagery Facility (PPIF), has the capability to process, print, and interpret information gained through tactical reconnaissance operations. It is also a self-contained unit. In other words, no matter where you are sent, as long as there is a water supply, you would still be able to operate the PPIF. The WS-430B complex is a self-contained complex consisting of 25 air, or ground transportable units, also known as shelters. The group of shelters have the capability of being deployed, either in part or whole.

Air Force Regulation 55-19, *Organization, Operation and Management of Photographic Processing and Interpretation Facility*, governs the operation and management of the PPIF. As implied in AFR 55-19, the prime function of the WS-430B is to support TAC units by processing and interpreting tactical reconnaissance imagery. All operations are directed to accomplish this mission in a timely fashion.

It was stated earlier that the WS-430B could be mobilized either in part or in whole. The most common configuration for mobility in a peacetime exercise is called a half-complex. A half-complex consists of 13 shelters. During wartime, any mobility situation would require movement of all 25 shelters. Even though only 13 shelters are deployed, there are enough shelters to fulfill the mission requirements. This is because each WS-430B complex consists of at least two of every type of shelter except the ES-73 series III printing shelter. So a half-complex takes a duplicate of everything that is left behind plus the ES-73 shelter.

As you may have determined, each shelter has a specific purpose to ensure that the mission is fulfilled. In addition to a specific duty, each shelter is assigned a specific number for designation.

Expandable final edit and inspection lab, ES-60B and ES-61B. The ES-60 and ES-61 shelters provide the work space and equipment required for final editing and inspection of film which has been processed and printed in the facility's other laboratories. The ES-60B and ES-61B laboratories also serve as the control access to the remainder of the facility and as central control points for power distribution to specific areas of the facility. In addition, they provide storage space, administrative areas, and personnel rest areas. The ES-60B laboratory also functions as a command post for the facility.

Continuous processing lab, ES-59A. The ES-59A shelter provides the primary rollfilm and paper processing capability of the facility and can be used separately to fulfill a similar need at a remote site if required. In all, a total of six ES-59A laboratories are used in a complete facility (three in each half-facility). Processing is done in a Versamat Model 11CMW Film Processor or the new Versamat Model 1140.

Expandable film titling and cleaning lab, ES-63A. The ES-63A shelter provides the equipment and controlled environment necessary for film titling operations and for production control of photographic film processed in the facility. In addition, the ES-63A laboratory includes film cleaning equipment and permits interim storage of in-process film.

Expandable interpretation lab, ES-64A. The ES-64A shelter provides the needed capabilities for support of normal tactical interpretation functions. Specifically, the laboratory is used in initial screening, detailed interpretation, indexing, and plotting of tactical reconnaissance information. It also provides a capability for storage of maps and other related data as required. A security file (safe) is included in these storage provisions. In normal situations, an ES-64A laboratory is installed in and used with each half of a facility. The laboratory is also capable of operation as a unit, independent of the facility. In such remote applications, only its connection to an electrical power source is required for normal operation of the laboratory.

Series I printing, ES-57D. The ES-57D shelter has capabilities for both continuous and step-and-repeat printing. Film to be printed here is normally processed in one of the ES-59A shelters. Continuous contact printing is done on the EN-6A(2) printer and manual contact printing is done on the EN-22 printer. Step-and-repeat printing is done on a Mark II-R5A printer.

Series II printing, ES-58D. The ES-58D shelter has the capability of producing projection prints. It is divided into a darkroom and a finishing room. Printing is accomplished on an EN-52A projection printer. A sink, print washer, and print dryer are also provided.

Series III printing, ES-73A. A Niagara Continuous Contact Printer provides the high speed continuous printing capabilities of the ES-73A shelter. The Niagara is the major piece of equipment in this lab, but it also has work space and film storage facilities. Although designed for use with the entire WS-430B complex, this unit can be used separately at a remote site when electrical power is provided.

Chemical mixing and distribution lab, ES-65A. The ES-65A shelter provides a capability for mixing, temporary storage, and distribution of the developer and fixer solutions required in the facility for normal film processing. The laboratory also includes provisions for mixing and storage of chemical solutions required by the radar film correlator-processor(s) sometimes installed in one or more of the facility's ES-59A laboratories. Correlator-processor chemicals would, however, have to be handcarried to the ES-59A laboratories, whereas the chemical solutions for normal film processing can be distributed by the facility chemical supply system. Two ES-65A laboratories are installed normally in a complete facility: one in each half-facility. Each ES-65A laboratory normally services the three ES-59A laboratories in its half of the facility.

Major elements of the ES-65A laboratory include four Pako Hydromixers; two mixing valves (one for each two hydromixers); two plastic, five-gallon mixing and storage tanks for the correlator-processor chemicals; and a portable mixer for utility purposes.

Sensitized materials storage shelter, FS-6A. The FS-6A provides refrigerated storage space for the photographic materials. Up to 4000 pounds (118kg) of material can be stored in this shelter. Materials can be transported in this shelter if preconditioning is given to them but only for certain specified times. This shelter can be used by itself when electrical power is supplied.

Expandable maintenance shelter, FS-7A. The FS-7A photographic maintenance shop contains the tools and associated equipment required for maintenance of the various laboratories and related facility-level interconnect equipment. The shop also includes storage provisions for necessary maintenance equipment, records, and spare parts. In addition, the shop includes an air compressor and tank which serves as the compressed air source for the facility's "wet shelter" laboratories. It also serves as an electrical power control and distribution center for the ES-65A laboratory and for the FS-6A storage shelters in that half-facility of which the shop is a part. Although normally used as part of a WS-430B facility (one shop in each half facility), the FS-7A maintenance shop can also be used as an independent unit, if desired. In such an application, only connection of electrical power to the shop is required for normal operation.

Management. The WS-430B OIC has overall responsibility for mobility. He attends all deployment briefings and gathers as much information as possible concerning the deployment. The NCOIC is responsible for supervising all portions of a mobility exercise or actual deployment. He reviews all procedures and checklists for accuracy, completeness, and compliance with directives. He coordinates all deployment activities and resolves problems.

The mobility NCO is responsible for developing mobility procedures and checklists for any operational requirement. He assigns personnel to mobility crews, sets up personnel processing schedules and maintains a status roster for personnel immunizations. Each packing and mobilizing team chief is responsible for seeing that each shelter is packed, inspected, and marshalled on time. He ensures the crews have the proper tools and equipment for mobilizing the shelters.

The maintenance NCO monitors the mobilization of the electrical generators and supervises maintenance personnel in disconnecting power and intercom cables and water, drain, and air lines. The air marshalling coordinator controls the WS-430B area checkpoint. As equipment passes this area, it is checked off on copies of the load lists.

The final inspector ensures that shelters have been placed properly. He signs appropriate forms certifying this action. The WS-430B NCOIC or a designated alternate is the final inspector.

The PPIF requires a great degree of specialized training to ensure proper combat readiness. Procedures must provide for practical experience in assembly, disassembly, and mobilization of the PPIF. To reduce wear and tear on the shelters, this program should be limited to the least amount of shelters necessary to achieve desired proficiency. Personnel should receive training and be certified skilled at least twice a year.

The other preplanning step is for a person with a working knowledge of WS-430Bs to survey the new site for the complex.

Upon arrival at the deployment site, some preparation and planning is necessary before setup begins. Some considerations are the source of water, drain point, power sources, surface conditions, and the number of shelters deployed. After the plans are made, the shelters are moved to the site. The shelters are connected to the power, intercom, water, drain, and air lines.

In order for all personnel to be ready for instant deployment, each WS–430B complex will exercise a deployment at least twice each year. This means that the complex is mobilized and reassembled at least biannually. In addition, the personnel must process actual mission or previously exposed film during any such exercise.

Exercises (045):

1. What does the WS–430B facility provide the tactical reconnaissance units?

2. What is the function of the following shelters?

   a. ES–64A

   b. ES–57D

   c. ES–58D

   d. ES–73A

   e. ES–65A

3. What are the mobility responsibilities of the PPIF NCOIC?

7-2. Preparing the WS–430B Systems Equipment for Mobility

When it becomes necessary for a processing facility to be mobilized, certain procedures must be followed to ensure that the move is completed in a timely, orderly, and safe manner. Procedures for the mobilizing of the WS–430B are found in the Technical Order 10M1–2–5–11CL–1 (Mobility Checklist, WS–430B).

046. Explain the tasks performed when preparing a processing shelter for mobility.

Prepare Equipment for Mobility. Since each shelter performs tasks that are particular to that shelter, it is obvious that each shelter will have mobility procedures that are particular to that shelter. This fact requires that each shelter has its own TO pertaining only to that shelter.

Though there are a variety of tasks which must be accomplished when mobilizing a shelter, they can all be related to five basic areas. Even though the individual tasks vary slightly from one shelter to another, they are still commonly related with the five basic areas of cleaning, draining, disconnecting, inspection, and stowing and securing.

Clean. Prior to the shelters being mobilized, you must check to ensure their cleanliness. Cleaning is a day-to-day operation, but it is imperative that at the time of a deployment that all wet shelters are free from any type of spills. Shelters which contain liquids are known as wet shelters. The lines which carry the liquids have to be cleaned of any spills which may have occurred. This area is of great importance, because chemical spills can easily cause damage to metal and equipment in a very short period of time, so any uncleaned areas are considered potentially damaging. All lines should be cleaned to prevent premature aging. The cleanliness of the shelter must be upheld throughout the mobilizing.

Drain. Once the shelters are cleaned, the next area to deal with is the draining and the cleaning of the lines which carry the solutions and all chemicals and solutions in the machines. Cleaning is accomplished by running water through the lines and the tanks. After the water is run through, compressed air is forced through the lines to remove any excess water. This two-step process is known as purging a system. There must not be any solutions left within the shelters, and all tanks in the equipment must be dried. A common practice during mobility is to place sponges in the bottom of the tanks to help eliminate any excess water that remains within the tank or on the racks.

It should be stressed that whenever you are working around any type of chemical you must exercise extreme caution. Chemicals can cause a variety of damages to your skin, and even more if somehow taken internally. Severe damage of your equipment or even personnel injury could result with mishandling and/or carelessness.

Disconnect. After the shelter is completely drained and cleaned, everything must be disconnected. At this time maintenance will be involved. At no time will any operator disconnect any powerlines or air lines. Powerlines and air lines are the sole responsibility of Maintenance, except for storing powerlines in the shelters. There are other lines that will require disconnecting though, such as water, drain, and chemical lines. All these will be disconnected and left in an orderly fashion. The reason that they are left out is that after everything is disconnected, it must be inspected.

Inspect. At this time all the equipment is to be inventoried. Anything missing should be noted and reported to the NCOIC or mobility supervisor. In addition to quantity, the quality of the equipment must also be inspected. Any item which is damaged should be repaired on the spot or noted for future repair. Constant surveillance of the equipment will prevent finding useless equipment at the time of mobility exercise. All the equipment must be in good working order, as it will be used as soon as it reaches its destination. Finding out that you are missing or have damaged, useless equipment once you reach your new location could ruin an entire mission] Attention to detail and an attitude of professionalism will do a lot in preventing any mishaps during mobility.

Stow and secure. Once the equipment is accounted for and deemed usable, it must be stowed and secured. Stowing and securing is ensuring that everything is in its rightful place and is free from any movement which might cause damage either to that piece or to some other piece of equipment. Not only does each shelter have its own specific tasks, it also has its own specific equipment, and each piece of that equipment has a specific place to be stored during mobility transfer. Each shelter has a list and storage diagram of the equipment stowed, within that particular shelter. As each piece of equipment is stowed it should be checked off on the checklist. The lists and stowage instructions are printed in the TO for that particular shelter. The checklist and inventory lists should be kept on the door of each shelter.

Exercises (046):

1. Who is responsible for disconnecting and inspecting the power cables?

2. What are the five basic areas of preparing a shelter for mobility?

3. Explain how power cables are prepared for mobility?

4. How do PPIF personnel know what shelter to stow particular equipment in?

7-3. Preparing for Transport

The previous section dealt with tasks to be performed on the interior of the shelter, but there are many tasks on the exterior of the shelter which also need to be accomplished.

047. Explain the major steps in preparing the WS-430B for transport.

Remove Passageways. All shelters are connected by a passageway. These passageways are light tight and weatherproof. They are also basically a bridge from one shelter to another. The passageway is actually a floor support with a fabric cover surrounding it. These passageways can be zipped to shelters. An external insulating blanket surrounds the fabric cover and is held in place by a string attachment. The actual passageway shape is formed by the application of support rods. These rods are similar to tripod legs and are spring actuated. Removal of the passageways is basically simple. The external blanket is removed, the fabric cover is folded over the support rods which is compressed in length and held in place on the passageway base. Care should be taken to ensure that the rods are secure and will not come loose. Severe damage could be caused if the support rod springs to full extension suddenly. Actual arrangement of the components of the passageway will have the metal base with the support rods laying lengthwise in the center of it. The fabric cover will be folded and strapped onto that, with the exterior cover strapped over the entire assembly. The whole setup is placed within the shelter and is secured vertically by braces bolting the bridge to the floor. Each passageway contains A blanket, one passageway base, a fabric cover, and 17 support rods. If there are any parts missing during an inspection, it is a discrepancy.

Disconnect lines. Disconnecting lines from the shelter is a little more complicated than just unscrewing some hoses. Not only are there more than one type of line system, there are certain precautions that must be watched when disconnecting.

There are three different types of line systems in the shelter assemblies for a wet shelter. These are Ichemical supply, water, and drain; electrical; and *compressed air*. Since the compressed air is necessary to purge the other lines, it is the last line that will be disconnected. The liquid line systems are the first to be disconnected.

The shelters that have liquid line systems will be those shelters that do some of the processing or have some use for liquids. The chemical supply lines connect the ES-65 shelters (chemical mixing) to the ES-59 shelters (processing shelter). Some complexes no longer use this arrangement and opt for using mixing vessels in the processing shelters rather than transferring from one shelter to another. If the chemical mixing shelter is used, there are separate lines for the fix and developer. These lines contain no insulation (water and drain lines contain insulation) and have no provisions for the heating of the lines (water lines do). The water distribution systems (water lines) connect the wet shelters, or those shelters requiring water, to some sort of water supply. This supply can either be natural (lake, stream, pond, well, etc.,) or artificial (commercial supply, holding tanks, etc.,). With the use of the water, there is also a need to dispose of waste water. From this we have a need for the drain lines. Both the drain lines and the water lines can contain insulating blankets and heater elements, to prevent the water from freezing, in their design. Power for the line heating elements comes from receptacles near the drain fittings in the shelter walls.

As the lines are being readied for transporting, they should be flushed with water to clean them. Once they are cleaned, they must be purged with compressed air. A word of caution: when using compressed air, the utmost care should be taken to prevent any mishaps. If the instrument you are using for the compressed air should come loose from the compressed air supply, it could cause a serious injury. Before operating any type of compressed air device, ensure that all fittings are in place and secure. After the lines are cleaned, they are then flushed with the compressed air to remove any obstructions or moisture. They are then neatly stored with their respective shelter. The same procedures are used for all the lines.

A full complex will contain six 150KW generators. These supply 120/208 volts of power to the complex. Each shelter has a branch from these generators to supply its power to the shelters. From this supply the shelter receives its power for its lighting system, equipment items, and outlet receptacles within the shelter itself. As was mentioned before, there are also outlets on the exterior walls of the shelter. Within each shelter there is also a power panel consisting of a circuit breaker panel and control elements (switches). All of the power systems contain a variety of appliances that are used in routing the powerlines to various areas within and around the shelters. During mobility, all of the various pieces must be maintained to ensure proper function and safety upon reconnection. All electrical items are disconnected and rolled up. These lines are then stored in the shelter in its particular place. Though Maintenance will undoubtedly complete all the disconnection for the power sources, all personnel should remain proficient in case your assistance is required.

The last type of line system, which is the responsibility of Maintenance, is the compressed air lines. The main purpose of these lines are for purging plumbing lines in the wet shelters and for equipment in the maintenance shelters. As was mentioned before, extreme care must be taken when using compressed air. For most of the plumbing lines the pressure (measured in pounds per square inch) is 40 psi. If the pressure is not monitored closely, it could cause an extremely large amount of damage to the piece of equipment that you are working on. Procedures for the use of compressed air are found in operation and maintenance manuals for the shelters in which the compressed air is to be used. For transporting, you must ensure that the lines leading from the compressed air are free of defects or damages. All areas on the compressed air supply should be free of damage. Before Maintenance disconnects the lines, make sure that the air supply is off so that by disconnecting the lines no damage or harm will occur. Once the lines are removed they are rolled up and placed near the shelter in which they are used.

Purge Wet Vans. In addition to the chemical and water lines that were drained and purged during the interior preparation, there are also drain lines on the exterior which also need to be purged. This purging is accomplished with compressed air. The compressed air displaces or forces all the remaining moisture out of the lines. Removal of the moisture is necessary to prevent freezing and cracking of the lines during airlifting. The temperature in cargo bays of aircraft can and does go well into the freezing temperatures.

The drain connections of the shelters are located on the side of the shelter near the bottom. Once all the liquids are free from the drain lines, the lines are checked for dryness and readied for disconnection.

Stow. Once the passageways are assembled and the lines for the various solutions and power are disconnected and positioned, you can stow them. Each of the items have a specific purpose for their shelter. Therefore, it only makes sense that the item be placed in the shelter in which it is used. The solution lines and power cables are wrapped around steel rods screwed into the floor (and in a couple of cases, the ceiling) of the shelter. They are then strapped securely in place. The TO pertaining to that particular shelter will contain an exact location of how and where the item is to be placed when a deployment is in practice.

Fold Expandable Shelters. In a SW–430B complex, there are several shelters which are deemed "expandable/collapsible" shelters. All of the others are rigid in shape and size. The rigid shelters are somewhat smaller in size. The expandable shelters are ES–60 and ES–61, editing and inspection shelter; ES–63, film titling-cleaning shelter; FS–7, photo maintenance shop; ES–64 interpretation shelter.

Because of the design of this type of shelter, it is possible to adjust the size of the shelter to meet mission requirements and to allow for optimum space usage during transport. The TO pertaining to that particular shelter will give step-by-step instructions for either expanding or contracting the shelter. It should be noted that extreme care should be exercised when mobilizing this type of shelter. All equipment must be removed from the walls and placed into the center of the shelter. All outlets are removable in this shelter as are the lights. Everything is stored and secured to allow the shelter to collapse to a size of a rigid shelter. At that time it is handled in the same manner. All of the folding panels of the shelter are massive, meaning that they are very heavy. Extreme care must always be used when folding the walls, and especially when raising the floor and dropping the ceiling down.

Install Transporters. Even if a WS–430B shelter is being airlifted, it will usually have to be transported to the place where it will be airlifted. This requires the addition of wheels to the shelter to enable it to be towed to the airlift site. These wheels are known as Transporters.

The transporters for the shelters are kept in storage and they may have been left in there for quite a long period. Prior to installing the transporters for mobility, they must be checked and found safe to use. The transporters have their own TO which lists the tasks that must be taken for maintenance. There are areas for situations prior to use, during use, and during periods of nonuse. Each of the transporters also has brakes. These should be checked to ensure proper functioning.

There should be no movement of the shelters without first installing transporters. The following basic steps are included in fitting the transporters to the shelters.

Each of the transporters consists of two assemblies, the front and rear dolly assemblies. The front dolly is positioned at the end near the air conditioner and the rear is placed directly opposite it. The dollys must be aligned for proper use. The transporter is pumped up to a point of alignment with the shelter and is then locked into position on the shelter by connecting the struts from the transporter to the shelter. Two things of importance—during any assignment at a complex you will be issued safety (steel toe) boots. These boots should be enough to provide you safety from falling objects. But, prevention is worth a whole lot more than minor injuries, so exercise extreme caution. Also, the transporter is attached to the shelter by a strut. This strut is held to the shelter by a wing nut. During installation and removal, *DO NOT* stand in front of that wing nut. If the nut should decide to come loose and fly off at the time you are standing in front of it, the pressure behind would cause extreme injury. BE CAREFUL!! After the transporters are installed and everything is secured, you must check the operation of the brakes on the transporter. First, there is an air line which must be connected from the front assembly to the rear assembly. After that is hooked up, the brakes and all fastenings are checked. If all is as it should be, then it is ready to be connected to the other shelters for transport (towing).

Exercises (047):

1. How is a passageway packed?

2. When installing the transporters, where is the front dolly positioned?

3. How are the solution lines stowed in most shelters?

7-4. Purging the Plumbing System

In preparing a mobile facility for transport, one of your first tasks is purging and disconnecting the plumbing system. Because of the importance of this task, it is covered again to more depth.

048. Given situations related to improperly conducted purging tasks predict the probable results on photographic equipment or materials.

Purging. Purging the plumbing system is necessary when one of two conditions is encountered. First, when located in a cold climate and power is not available to operate the water and drain-line heaters during shutdown periods, the system must be purged. Second, purging is necessary prior to air shipment since the laboratory may be at altitudes where the temperature is below freezing.

Purging the chemical supply lines, chemical replenishing system, and silver recovery system is the first step in purging the plumbing system.

Chemical supply lines. In addition to the reasons for purging the plumbing system given above, the chemical system requires further attention. When you change the formula (type) of the processing solutions to meet changes in mission requirements, you must also drain all chemical lines and tanks. Furthermore, chemicals are corrosive and must be flushed from all surfaces they contact.

Flush the chemical supply lines with warm water long enough to completely dissolve and remove the chemical residue within the lines and associated equipment. Remove any water remaining in the chemical lines by air purging at approximately 20 psi pressure.

Chemical replenishing and mixing system. After the chemical supply lines have been drained and flushed, you must treat the other chemical systems. These systems include the replenishing and mixing system, the processor, and related lines within the laboratory.

After you have drained all processor tanks and the chemical holding/mixing tanks, flush the holding/mixing tanks, and then partially fill them with warm water. Remove the developer filter cartridge and allow the water contained within the holding/mixing tanks to gravity feed into the processor, flushing the processor replenishment systems. After a short time of gravity feed, operate replenishment pumps with the flow set to maximum. If necessary, use Kodak system cleaner in the developer holding/mixing tank.

While you are flushing the replenishment systems, remove and clean the wash racks. Also, while these racks are out of the processor, clean the entire unit, both inside and outside. At this point, interrupt the basic procedures to drain the silver recovery system.

Finally, when the system flushing and cleaning is satisfactory, dump the water remaining in the holding/mixing tanks and purge the system with air pressure.

Silver recovery system. After much of the chemical replenishing and mixing system drain procedure is completed, the silver recovery system must also be drained. The draining procedures that follow are applicable to the Argenta Model 105 silver recovery unit.

As with all electrical equipment, the first thing that must be done is to disconnect the unit from the power source. When this is done, drain the filter-flowmeter and both large and small recovery unit tanks. While the drain valves are still open, flush the tanks with warm water.

Since the remaining procedures depend primarily on the operation of the unit, reconnect it to its power source. Be sure you have closed the drain valves and filled the tanks with warm water. Before you operate the recovery unit, several other tasks should be performed. These are:

(1) Inside the processor, position tubing from the fixer line selector valve to pump into fixer overflow tanks. Open the valve in fixer overflow line.

(2) Open the circuit breaker, disconnect the electrical power cable from the developer replenishment pump, and close the circuit breaker.

(3) Open the developer and fixer mixer chemical shutoff valves and close the developer and fixer solution shutoff valves.

(4) Partially fill the fixer replenishment tank with warm water.

(5) Turn on fixer replenishment pump and check for flow of water.

Now, the silver recovery unit recycle pump may be turned on. With the recycle pump operating, check for the flow from the recycling (large) tanks to the processor, and from the tailing (small) tank into the drain line. Continue this operation until the flowing liquid is clear. When clear flow is obtained, shut off the silver recovery unit recycling pump, and return fixer selector valve and associated tubing to their normal position. With the power supply disconnected from the silver recovery unit, drain the tanks and system lines. Blow out the lines and fittings with compressed air (at 5 to 10 psi maximum pressure). Reconnect the unit to its power source and close the fixer overflow valve in the processor.

Water lines. After the chemical lines, the chemical replenishing system, and the silver recovery system have been purged, the water lines must also be purged.

Turn the water heater and the water control system circuit breakers off, then set the sink temperature control to midrange and open the sink mixer drain valve to MAXIMUM. Let water flow into the sink until its temperature becomes ambient.

You must now close the main water inlet valve to the laboratory. Next, open the pump drain valve and the printer cup shutoff valve. When this is done, turn the water pump off and position circuit breaker at OFF.

At this point, all lines and valves must be cleared of water. Open the sink mixer drain valve and turn the sink mixing valve temperature control through its complete range repeatedly until no more water flows. Connect drain hoses to the processor hot- and cold-water supply drain valves. Direct the hoses into a bucket, floor drain, or sink. Adjust the thermostat mixing valve to MID-RANGE and slowly open the Fotopanel water shutoff valve until all water has been cleared. Close all valves.

After these tanks are completed, verify that the maintenance shop air supply is available at 40 psi. When this is confirmed, slowly open the shelter air shutoff valve.

Purge the lines to the developer and fixer holding/mixer tanks by opening the hot- and cold-water shutoff valves. After purging, close these valves. Next, open the chiller and condenser drain valves and their plumbing system drain valves. After draining, close these valves also. The last step in this procedure is to purge the pump lines, using the condenser and pump line drain and the pump drain valves. Close the air shutoff valve while the pump drain valve is open. After the air pressure has dropped to ZERO, remove the cap from the primer cup and open the primer cup shutoff valve. This permits water to drain from the primer cup and line. Close the primer cup shutoff valve and open the air shutoff valve. Finally, after the pump is clear of water, close the pump drain valve.

If there is any doubt about the system being clear of water, repeat all the preceding steps before you proceed.

After you purge all systems, shut off the air pressure to the laboratory and relieve these systems of any air pressure that might remain in the lines. This can be done by opening the mixer drain valve as well as the water inlet and drain valves.

Even with utmost care in accomplishing the above tasks and following the procedures exactly, special attention must be given to selected parts of the system. This attention entails:

(1) Removing, drying, and reassembling the temperature control mixing valve checks and strainers at the sink.

(2) Removing water trapped in the Fotopanel case.

(3) Removing excess water from the thermometer well.

(4) Draining the flowraters.

(5) Removing water trapped in the processor heat exchanger, flow switch, standpipe, and recirculation pump.

Next, the water system filters must be removed and reassembled with dry filter elements. Remove the water pump strainer from the pump, disassemble, clean, drain, and dry as necessary. Reassemble and reinstall on the pump.

Finally, remove the water supply hose from the water inlet fitting when water is no longer required for other shelters. Open the water shutoff valve, drain, and install the protective cap on the water inlet fitting on the power panel.

Exercises (048):

1. A change in mission requirements demands that "Versamat" developer type 641 be used instead of "Versamat" type A. The chemical system was not purged for this changeover. What effect can be expected for this situation?

2. One of the procedures for purging the chemical replenishing and mixing system suggests the use of Kodak system cleaner in the developer holding/mixing tank. However, according to the procedures, flushing with warm water and seasoning the system is not required. If these TO procedures are followed verbatim:

   a. What effect will this action have on the new developer?

   b. What result can be expected on the film?

3. Draining the waterlines was not done before a mobile photoprocessing facility was air transported. What can be expected during setup at the new location?

7-5. Facility Setup

All the preparation that is done for transporting and mobilizing would be useless if there wasn't a place for the complex to be mobilized. Prior to any preparation for mobilizing, the site for the new facility is found. The site is chosen very carefully. There are certain requirements which must be met in order to allow the mission to be accomplished. A major necessity is that a water supply must be available. This supply can be either manmade or natural. Electrical power is supplied from the generators. There must be enough space for you to place the number of shelters that you have into a logical working arrangement. The shelters must also be placed near an area that can be used for flying aircraft. The prime mission deals with the reconnaissance, so it must support the flying mission. The

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ground area must be accessible to facilitate the mission accomplishment and should be fairly level. This will aid in moving the shelters into place and allow for quick removal if necessary. The type of ground must also be considered because of the weight of the shelters. These are basically some of the things which must be considered prior to moving the complex. But, after the site is chosen and the shelters to be moved are in place, setup comes next.

049. Explain the major steps in facility setup.

Remove Transporters. The first thing to do is to arrange the shelters in the approximate arrangement that will be used. All the dimensions should be accurate to ensure that the passageways will fit and the dimensions for the lines aren't exceeded. Once all that is accomplished, the transporters can then be removed. Again, extreme care should be taken when handling the transporters. After the transporters are moved, they are then hooked together and placed in their storage areas. The TO for the transporter states all the care that must be given prior to and during storage.

Level Shelters. Each shelter has leveling jacks attached to the outside of each corner. Since all the shelters must be at nearly the same height, the tasks of leveling the complex can be very lengthy. The first thing to do is rough level all the shelters. By this, you should ensure that one side of the shelter is not a foot higher on one side than on the other. Once all the shelters are rough leveled, you should check the general level of the area in which you are setting up the complex. If the site was chosen correctly, it should be fairly level. If this is the case, leveling procedures can begin with the first shelter and work outward. The main objective of the leveling procedure is to ensure that all the shelters are the same height. Ground clearance should be kept to a minimum to just ensure that proper drainage is available. The shelters should be leveled to a point to where there is only a 3-inch deviation overall. By not watching closely, the last few shelters could easily exceed the maximum adjustment capability of the leveling jacks.

Unfold Expandable Shelters. Once the shelters are leveled, the expandable shelters can then be unfolded. The shelters contain support braces which should be used to ensure personnel and equipment safety. Upon raising the roof, the floor is lowered and the walls are expanded. Nothing should be removed or put into place until the roof and walls are secured to their final positions. At this point the light sockets can then be replaced, along with the outlets and electrical connections. Once these are in place, the equipment which was secured in the shelter can be returned to the place where it belongs. Care should be taken to ensure that all outlets and connections are properly secured to avoid injury.

Connect Lines. Once the shelters are in place and the equipment is attached where it belongs (expandable shelters), the various lines can be installed. As an operator, you will be responsible for the water, drain, and chemical lines. If the chemical mixing shelter (ES–65) is not to be used, you may not have to install the lines from that shelter. All those shelters which use water must have a water supply line and a water drain line. Those shelters which use the drain lines will have the lines connected to the shelters at the side of the shelter. They will also have the drain line heater cables connected from the exterior outlets. The water supply lines will also have heater cables connected to them. The water supply and drain lines will have insulator blankets installed on them to aid in prevention of freezing of the lines. All lines and fittings should be checked for good repair to ensure that no malfunction will occur during operation.

After the liquid line system is installed, maintenance will install the air line system. The air lines will be routed from the FS–7 shelter (maintenance shop) and the wet shelters. An air line and an air manifold assembly to regulate the pressure, and the compressor within the maintenance shelter are the basic parts of the air supply system. When the lines are installed and they are going to be used for transferring chemistry, the pressure of the air should be kept about 20 psi. When the system is used to purge plumbing lines, the system air pressure should be used at 40 psi. It is necessary that the air pressure be kept constant throughout the system or damage may occur. If a compressed air source is used that is not located within the shelter that the air is used in, the air pressure must never exceed 75 psi. Flow from the FS–7 shelter to the other shelters is accomplished by use of the shutoff valve located within the maintenance shelter. Each shelter can shut off the air coming into the shelter by using the shutoff valve located in that particular shelter. The actual procedures for shutting off and turning on the air pressure are given in the TO.

The last lines to set up are the power supply lines. These will normally be set up by maintenance personnel. If, however, it becomes necessary for you to assist the maintenance personnel, you should have an understanding of how the lines are set up.

Power for a half-complex is provided by three generators. The power runs from the generator to a load transfer switch into three separate power lines. Since a half-complex consists of 13 shelters, each power line supplies either three or four shelters. One shelter in each group acts as the control source and distributes the power to the other. The power system for a full complex is the same as the half-complex, only doubled. If there is a full complex in use, the power is distributed for startup one half at a time.

Starting up the power to the shelters is more than just throwing a switch. The three main shelters (control sources) are powered up first. Once the control sources are up, power can be delivered to the shelters in its group one at a time. All the other shelters are powered up in this manner until they are all complete. Extreme caution and adherence to all procedures should be stressed to ensure your personnel's safety. The power sources can deliver large enough amounts of voltage to cause severe injury or death, so adherence to those procedures should never be waived. All procedures should be followed in accordance with the applicable manuals.

Install Passageways. Once the lines have been connected, the passageways can be installed. The passageways are stored within the shelter to which they belong. The assembly should be taken out and inspected for damage. If there is none, the parts are removed from the bridge. The bridge is placed between the two shelters and secured. The support rods are placed under the fabric cover to give the passageway its shape, and lastly the insulating blanket is secured over the fabric cover. Details for installation of the passageways are listed in the TOs for the shelters. Caution should be used when dealing with the support rods as they are spring loaded and could cause severe harm or damage if mishandled.

Exercises (049):

1. What is the main objective when leveling a shelter?

2. How many generators would be needed to power a half complex?

3. When the air line system is installed, what regulates the pressure, and what should the pressure be?

7-6. Prepare Equipment For Use

During transport, the equipment in the shelter is stored according to the conditions required for air, sea, rail, or road travel. Therefore, tiedowns, anchors, guards, etc., must be removed before the equipment can be used.

050. List the functions that must be performed to prepare a processing shelter for use.

Preuse Preparation. The first step in preparing the ES-59A laboratory for use is to ensure that all laboratory circuit breakers are turned OFF. Then, after the facility-stored equipment has been removed and the air-conditioner made operational, attention is given to the continuous processor. Preparing this processor for use involves (1) removing tiedowns and padding, and (2) removing roll takeup and roll adapters from storage and installing them on the processor.

In addition, other equipment is contained in the laboratory and must be prepared for use. This accessory equipment is the sensitometer, maintenance kit, B-5A portable processor, and silver recovery system.

After all equipment has been made operational, attention must be given to the plumbing and electrical systems. Finally, the intercom must be connected and final miscellaneous checks as prescribed for the facility must be performed.

Exercises (050):

1. List ten functions necessary in preparing the ES-59A laboratory for use.

051. Tell whether specific deficiencies in quality might occur as a result of improper processor preparation.

Effects On Product Quality. Not all of the laboratory preparation procedures listed above will influence product quality, even though they must all be accomplished if the laboratory is to be fully serviceable. Most important to production capabilitiy is preparing the continuous processor for use.

In the following paragraphs we will discuss the procedures for preparing the processor for use. Keep in mind that the processor still needs to be charged with chemicals and certified, both mechanically and chemically, prior to use for processing mission film.

The processor is attached to the floor of the shelter with tie rods and brackets. These were used to protect the processor during transport. In preparing the processor for use, these tiedowns and all cushioning must be removed.

The initial preparation task is to remove the tie rods that held the processor firmly in place during transport. Since they will be used at some later date for subsequent transporting, these assemblies must be protected. Replace the bolts and cotter pins on the tie rods and stow the entire assemblies under the processor. It is not required that other tie rods and brackets be removed from the processor. However, if you do remove them for safety reasons or to facilitate processor operation, stow them under the processor.

When the necessary tie rods and brackets have been removed and stowed, you still must remove the cushioning from the inside of the processor. Remove the straps that hold the tank covers in place and then set the tank covers aside. Remove the top racks and roller racks individually, remove the cushioning, and replace each rack in its proper location. The final preparation step is to ensure that the processor is level. If it is not, adjust the leveling attachments.

The last two procedures as listed are extremely important if the processor is to certify and if subsequent mission material is to be processed successfully. From previous discussion in this CDC, you will recall that each roller rack and top rack (crossover) has only one correct location within the processor. If these are positioned in any other location, a material wraparound can, and in most cases will, result. Leveling is important in that binding of rollers, gears, etc., might result if the processor is higher at one corner than at the other three. This binding can also result in material wraparound and scratches and other physical defects.

Exercises (051):

1. Which of the following negative characteristics could be related to improper processor preparation?

   a. Crimped edges.

   b. Excessive density.

   c. Fog.

d. Abrasions.

e. Low gamma.

f. Low resolution.

2. What improperly conducted processor preparation procedures could result in a material wraparound?

052. Given a list of undesirable negative characteristics, determine which factors could have caused each characteristic.

Determining the Cause of Negative Defects. After the processor has been set up for use according to the foregoing procedures, it still must be certified. During certification, the operator must use his or her past experience in determining the reasons for physical defects. It is obvious from past discussions that all defects, regardless of cause, must be eliminated. However, at this time, the decision must be made as to whether the defects are a direct result of shelter and equipment transport, or normal circumstances.

During transport, all facilities and equipment undergo great amounts of stresses, strains, vibrations, etc. Furthermore, when the facility is being prepared for shipment, and when it is being positioned after shipment, additional jolts, bumps, etc., are common occurrences. All of these increase the possibility of damage to the equipment or slight shifting from its original tiedown position, even though the tie rods, brackets, and other anchors might have been used properly.

It is because of these facts that original mechanical certification after facility setup is so demanding. As an example, material fog obtained from a processor in a fixed facility can be caused only by a limited number of things. This same fog produced during initial certification of a relocated facility can also result from these same things. In addition, it can be produced by light leaks in the film loading room (shifting of the processor, a door that does not close snugly, an air-conditioning unit that cannot be positioned properly, etc.), or even a top cover or side paneling that does not fit properly.

Such an example as discussed above outlines the problem facing the imagery production technician. He or she must not only know the causes of material defects or equipment malfunctions common to fixed facilities, but through deductive reasoning, logically conclude other causes of such defects and malfunctions that might result from transporting the shelter.

Let's consider other examples. Any technician who has experience with the "Versamat" processor knows the common causes of material wraparound. But what might happen if the transport roller racks in this processor became warped or misaligned during transport? Could these factors, unless corrected, result in a wraparound? The answer, of course, is yes. The same principle holds true for solution and water flow. There is a much better chance of foreign material being introduced to these systems during transport while they are in the dry state than there is in a fixed facility. If not purged prior to use at the new location, these systems cannot function properly.

Other examples could be stated, but these should be sufficient to illustrate the need for complete mechanical certification after setup and before use.

In conclusion, we can only reemphasize that the same defects can be encountered in both fixed and relocatable facilities. However, there are many more potential causes of such defects when the equipment has been moved from one location to another.

Exercises (052):

Below are three undesirable characteristics encountered during initial certification of a relocated processor. Would these characteristics most likely be the result of shelter relocation or normal circumstances (as would occur in a fixed facility)?

1. Material wraparound caused by a warped roller rack.

2. Decreasing gamma resulting from foreign matter retarding the replenisher flow.

3. Inoperative recirculation pump.

7-7. Post-Transport Inspection

When setting up a mobile photographic facility, the first thing that must be done, after positioning the shelters, is to inspect each shelter and its contents.

053. State the most probable malfunctions if complete inspection is not made on new or relocated equipment.

Before the individual shelters can be used, each must be checked for damage that might have occurred during transport. The following paragraphs briefly discuss the suggested inspection items.

First, the photographic materials shipped in the shelter under cold storage conditions should be checked for possible emergency handling action. Many times during transport, the sequence of planned material use according to expiration date is lost. Therefore, each roll or box of material must be checked for expiration date, and that nearest its expiration date used first. A second consideration is that during transport, the cold storage shelters are not connected to a power source for maintaining refrigerated conditions. Therefore, if the temperature within the shelter rises above the maximum safe level, the material must be tested for the effects of improper storage conditions. Many times, the material stored in these shelters can be used first during production, thereby salvaging many thousands of dollars in materials that would otherwise have to be discarded.

The shelter exterior and transporter should be inspected for evidence of major damage incurred during transit. Major damage to shelter exterior will, in many cases, result in fogged material caused by light leaking into the shelter during material handling. Damage to transporters should be identified as soon as possible and corrective action begun immediately. This is only to ensure their availability for the next mobilization.

Expansion shelter laboratories should be examined for proper expansion and for evidence of damage or problems on expandable sides of the trailer. Damage could render these shelters extremely difficult, if not impossible to expand. Such damage should be determined and repairs begun immediately to preclude extended shelter downtimes.

Laboratory interiors should be checked for damage and general condition of the shelter and equipment. Damage to lines for solution or water, interior walls, electrical circuits, floors, etc., that will interfere with the successful use of the shelter during production, must be corrected immediately. Other minor damage can be recorded and corrections made as time permits.

Laboratory-stowed equipment, especially processors, must be inspected for operational condition. If the processors were not properly anchored, their position might have shifted during transit. If shifting occurred to any great extent, the film loading/feed end will no longer be light tight. Entire rolls of valuable original material can be lost under such circumstances.

Exercises (053):

What is the chief danger if each of the following inspections is not conducted properly?

1. Sensitized materials.

2. Laboratory-stowed processors.

3. Expansion laboratories.

7-8. Preventive Maintenance and Discrepancy Reporting

Your facility is complete. It is certified and ready to go. All your shelters are completely functional. At this time you should place the future into your mind. You have done an excellent job to this point to get the shelters set up and running. Now the real task is to keep it running in the most efficient manner possible. Day by day you must ensure that you are able to meet mission requirements. At this point you will begin what is known as preventive maintenance—preventive maintenance because you will be doing tasks which will prevent maintenance personnel from having to stop production of a shelter for something that could have been prevented.

054. State the procedures when applying preventive maintenance.

Applying Preventive Maintenance Procedures. For a facility to operate properly, the shelter and its equipment must be kept in good operating condition. Periodic inspection and routine maintenance is performed so that any defects can be detected and repaired to try and avoid breakdowns. Routine maintenance consists of such things as adjusting, tightening, and replacing components necessary to ensure reliable operation of the laboratory. These units must also be kept clean as possible to guarantee performance and to facilitate inspection and maintenance. The production control and quality control sections are responsible for ensuring that each piece of equipment is certified on a timely basis. These certifications are needed to identify a potential problem that cannot otherwise be found through inspection. Once a problem has been noted, it must be corrected immediately. For instance, during the physical certification of a continuous processor, emulsion scratches appear. The operator seeks to identify the cause. Through the isolation process, he finds that a blower tube in the drybox is out of position. By simply snapping the tube back into position the scratches are eliminated without further maintenance. On the other hand, the scratches are produced by a processor rack that contains a loose chain. This must be recorded and Maintenance notified.

Inspection procedures should determine the necessity for cleaning the laboratories. All components, connections, recesses, and painted surfaces should be free of dirt, dust, and other foreign matter. When a surface is painted to prevent the spread of corrosion, it must first be cleaned thoroughly, then treated with a wash primer or metal conditioner before refinishing. In most cases preventive maintenance procedures are listed in the shelter's TO or equipment checklist.

Reporting Discrepancies. Production Control coordinates with Maintenance on the status of the equipment. When an equipment defect occurs, the operator informs Production Control. Production Control fills out an AFTO Form 349, Maintenance Data Collection Record, requesting maintenance support. In addition, the PC and Maintenance ensure that the discrepancy is recorded on the shelter's AFTO Form 244, Industrial/Support Equipment Record, showing the operability of its equipment. Depending on the nature of the problem, it is assigned a priority and completed accordingly. When the problem is found, it is important to let Maintenance know the complete details concerning it. If you state the Versamat is functioning incorrectly, it could take hours to find the problem. State exactly what is wrong and how you found the discrepancy. With that on file, when they come to fix the equipment they will know right where to start. In addition to helping by brevity, a history of the discrepancies is also kept by Maintenance. This necessitates the use of the form. The history will allow Maintenance to look for recurring problems in any of the equipment.

Exercises (054):

1. Who is responsible for the certification and inspection of equipment?

2. What forms are used to record equipment defects?

3. What is preventive maintenance?

Computer Applications

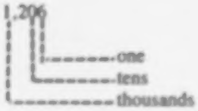
A COMPUTER IS simply a tool which allows you to do your job better and faster. But it will only do what it is told to do, nothing more. A computer is told what to do by way of a program. And a program is simply a set of instructions telling the computer what functions to accomplish or what questions to ask.

8-1. Computer Languages

In order to discuss the use of computers in reconnaissance, we must first know some of the basics of computers. The first thing you must be able to do is to communicate with your computer. The art of communication relies on knowing the language of the person or machine you are trying to communicate with. All computer languages are built on numbers. You will need some background in numbering systems in order to understand computer languages.

055. Given a list of numbering systems, indicate their use.

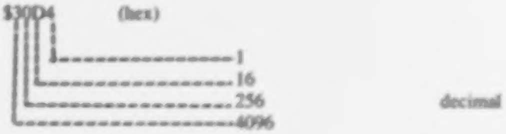
Numbering Systems. The most common numbering system is the decimal system which consists of ten digits, 0 – 9. When counting with the decimal system, you progress from the digit 0 until you reach the digit 9. Once the 9 has been reached, counting higher will cause a "carry" to the next column. The value of a decimal number is determined by the value of a digit and it's place in the number. For example:



The value of this number is determined by multiplying the value of each digit by the value of the column the digit is in. Even though the zero has no value, it holds a place and keeps all other digits in their correct places.

The hexadecimal numbering system is often used when writing programs with an assembler, debugging a program with some operating systems, and writing some basic programs. Even though it is not your job to write programs, from time to time you may find it necessary to list a program and make minor changes.

The hexadecimal numbering system is a little confusing at first, but it is actually very similar to the decimal system. Its digits range from 0 through F, and each place or column has a different value than in the decimal system. When counting in hex you would begin with zero and progress until reaching the F (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F). Once the F has been reached, counting higher will cause a carry to the next column. The value of a hex number is determined by the value of the digit and its place in the number. For example:



The value of this number is determined by multiplying the value of each digit by the value of the column the digit is in. Since a number in decimal will have a different value in hex, it is necessary to distinguish between the numbering systems. Most often a "$" is used to prefix the hex number. For example, the number 103 in decimal has a value of one hundred three, while in hex the value would be 259 decimal. From this point on, all hex numbers should be prefixed with a "$."

The binary system is important in the computer field because all entries into a computer are converted into binary for storage. In the binary system, there are only two digits, 0 and 1. Counting higher than 1 would cause a carrying to the next column. Each column is referred to as a "bit" when referring to its use in the computer. Eight bits equal one byte. Counting in binary is accomplished as follows:

00000000 = 0
00000001 = 1
00000010 = 2
00000011 = 3
00000100 = 4

In an eight-bit machine, you can count as high as 65,535, or $FFFF. In a sixteen-bit machine, the counting can be carried as high as 286,326,784 or $FFFFFFFF, and there are 32-bit computers!

For humans, counting or writing in binary is extremely confusing. For this reason, programs are written to accept input in either decimal or hexadecimal and then converted to binary for storage in the computer.

Exercises (055):

1. What is the most common numbering system?

2. How do you count with the decimal system?

3. Why is the binary numbering system important?

4. When would you use the hexadecimal numbering system?

056. Explain the use of machine languages.

Computer Languages. Every computer made is capable of understanding one language—machine language. Machine language is the binary interpretation of instructions. The letter A on an eight-bit computer would be represented by "01000010." Early computers had to be programmed by using this binary machine language. Because of the confusing nature of binary programming, other methods were developed to ease the task of programming.

Assembly Language. Assembly language programming uses a group of instructions unique to a given central processing unit (CPU) to perform a given task. Since the instructions are easier to understand than their binary interpretation, writing programs using instructions are much easier. An assembler is a program that will allow you to enter the instructions and code them into what the CPU will understand—machine language. An example of an assembly language program follows:

```
            ORG     $1000
START       LDA     #$ 16
            STA      $ EA
           CLRA      $ EB
            RTS
            END     START
```

When this assembly language program is entered into an assembler and assembled, the assembler will code each instruction into machine language or binary equivalent. An example follows:

```
          START      ORG   #1000
1000 8616            LDA   #$ 16   put $16 in A
1002 97EA            STA    $ EA   store A at $EA
1004 4F             CLRA           make A = 0
1005 97EB            STA    $ EB   store A at $EB
1007 39              RTS           Return
                     END
```

The first column on the left is the location in the memory. Each may be thought of as a box capable of holding one byte, or one instruction. The second column is the hexadecimal representation of the instructions. Even though the assembly shows us hexadecimal equivalent, what is actually in memory is the binary equivalent. The third column is the label field. This field is used to name subroutines and is not converted into machine language. The fourth column is the instruction or mnemonic field. This field is used to enter the instructions of the program as well as instructions to the assembler. ORG and END are instructions to the assembler and are not converted into machine language. The fifth column is the operand field and is used to enter a number into a register or store a number into a location in memory. Most assemblers allow a sixth column for the entry of comments. Comments are necessary so another person can read a program and know what is intended.

When the above listing is assembled into memory, the second column becomes the program. When executed, the computer will begin to do faithfully what it was told to do. First, it loads the A register with $16 and then stores the A register ($16) at location $EB. Finally it returns from where it was called. All of this was necessary just to put $16 into location $EA and 0 into location $EB. This simple example program is only eight bytes long, from $1000 through $1007. A quality word processing program is often longer than 16,000 bytes.

Assembly language is time consuming, confusing, and requires a lot of training just to be able to use the instructions set of a CPU.

Basic. BASIC is a language written for the average person. A program written in BASIC can be understood more easily, is simpler to write, and is easier to debug. A program written in BASIC might look as follows:

```
10 Poke $EA, $16
20 Poke $EB, 0
30 End
```

This program accomplishes the same as our assembly language program. If it accomplishes the same thing, is easier to write, and is simpler to debug, then why program in assembly language at all? The answer is speed. The assembled program will execute 25 to 100 times faster than the BASIC program. This is because each instruction of the BASIC program must be converted into machine language before the CPU can execute the instruction. In this example the speed difference is minimal due to the shortness of the program. But on a large program, the time difference is substantial.

As you can see, writing a program can be very time consuming and confusing. Languages were written to make this job easier, but the language must be learned. BASIC is easier to learn because it is like the language we speak. However, writing a program in BASIC will execute more slowly than one written in a language the computer can understand directly, without an interpreter.

There are many more languages in the computer world. However, all of them must be converted to a machine-readable form for execution. PASCAL, FLEX, FORTH, UNIX, OS-9, LOGO, MSDOS, etc., are all languages made to operate on given computers. The advantages and disadvantages of each are not important at this time. All serve one main function: to allow the writing of a program to tell the computer what to do.

Exercises (056):

1. Why is assembly language programming preferred over programming in BASIC?

2. What is the main advantage of programming in basic?

3. What must the computer do before it can execute a program other than assembly language?

4. What is machine language?

8-2. General Hardware

A computer system is made up of many components. Some of these components are essential for the operation of the computer while others give the computer more capability. Most of the computer's components are explained below in general terms because of the differences between various brands of computers.

057. Given a list of computer components, explain their uses.

Keyboard. The purpose of the keyboard is to give the user a means of putting information into the computer. Most computer keyboards are designed like a typewriter to allow familiarity for typists. In addition, many computer keyboards will have a numeric pad and function keys. The numeric pad is to allow the easy entry of numbers and is often designed like a calculator with +, =, −, ×, etc. Function keys, often labeled F1, F2, etc., are special keys designed to perform a given function. With one program, F1 may list the contents of the screen to the printer, while with another program, F1 may pause the program.

Monitor. A monitor is a CRT screen much like your television screen which is designed to receive a video signal from the computer and display it. Most monitors have twice the resolution than a television CRT, or more, due to a finer scan width. This allows very sharp graphics and a readable screen of 80+ columns.

Monitors come in many sizes and types. Most of today's monitors are medium to high resolution; green, amber, or color; and many include audio. They all serve one main function: to allow a visual representation of what is going on inside the computer.

Card cage. A computer card cage is simply a method of expanding the capability of your computer. When a card is plugged into the card cage of your computer, you may increase the memory available, add another language, or allow the use of IO (input-output) devices such as printers, plotters, disk drives, or modems.

The card cage usually is located internally within the computer. Opening the computer should be done only by a qualified person. Inserting or removing a card with the power on may damage both the card and the computer.

Memory. As mentioned earlier, a computer is capable of doing only what it is told to do. The computer must store these instructions in memory. When necessary, the memory is recalled and the functions are accomplished. Each memory location is referred to as one byte and may be 8 or 16 bits long, depending upon the CPU.

Memory within a computer may be all of one type but most often is a configuration of different types. The two most common types are ROM and RAM.

ROM stands for read-only memory which simply means you may read from the memory but not write to it. In other words, what you enter from the keyboard cannot be stored in ROM. Most often ROM is used to store a language or interpreter because it is always there. When the computer's power is turned off, the information in ROM is retained.

RAM stands for random-access memory which means you can write to it as well as read from it. When the power is turned off, or even fluctuates, the information in RAM is lost. Since RAM can be written to, this is where information entered from the keyboard is stored.

Memory is measured in K bytes (K = 1024 dec). Each memory location may be thought of as a box to store one piece of information. A computer with 256K of memory may actually have 32K of ROM and 224K of RAM. The amount of RAM indicates how much room you have to store your information.

Media Storage/Firmware. Since RAM loses its memory when the power is turned off, it would be nice to have somewhere to store this information before you turn off your computer. This will prevent you from having to enter the information from the keyboard again.

Tape. Audio tape is sometimes used to store information before turning off the machine. The memory is stored on tapes as high and low beeps representing the binary 1's and 0's of the memory. Once recorded, the binary beeps on the tape may be reloaded into memory the next time the information is needed. The quality of the tape used is dependent on the tonal range of the binary beeps and the speed of the information coming from the computer.

Audio tape consists of iron oxide particles on a plastic base. Each particle has the ability to store a magnetic charge which is later reproduced into the sounds that were recorded. Since this tape is subject to any magnetic field, care must be taken to store it in a safe place away from generators, motors, speakers, or any area where magnetism may be present.

Disk. There are two main types of disk drive systems in use today, the hard disk and the floppy disk. Both are used as storage devices for information and, assuming they are stored properly, will retain the information for years. The technique of storing information on disk is similar to that of tape, although greatly improved. The disk contains iron oxide crystals (chemically produced) on a mylar base. As the disk rotates, information is stored magnetically in binary format. The advantages of disk over tape are the speed of information transfer and the amount of storage ability.

A hard disk differs from a floppy disk in many ways. First, the iron oxide crystals are packed much tighter on a hard disk, allowing much more information to be stored. Many hard disks are capable of storing 5–10 megabytes or more. Hard disks are much more expensive than floppies. This is due to the critical controls in making the disk as well as the ability to store so much information. A hard disk is installed in the drive in a dust-free atmosphere at the factory and never removed unless Maintenance requires it.

Floppy disks are less critical in handling and much less expensive. The amount of information a floppy disk can hold is in the range of 192K, depending upon the computer's operating system. Since the floppy is fast, convenient, reliable, and relatively inexpensive, this is the type of disk you will most likely be using. The floppy disk is most commonly available in 5 1/4- and 8-inch sizes, the differences being the amount of information storage.

The make up of a floppy disk is quite simple. The housing protects the disk from dust and fingerprints. Attached to the housing, on the inside, is a cleaning fiber that cleans the disk surface as it rotates inside the housing. When the disk is inserted into the drive and the door is closed, a gripper grabs the disk at the hub hole. When the drive motor is turned on, the gripper rotates the disk inside the housing. The purpose of the hub reinforcement is to reinforce the hub hole. Over a period of time, the hub hole may lose its shape which will cause slipping. Since the disk rotates at 300 revolutions per minute (RPM), any slipping could prevent information from loading properly. Information is stored on a disk in the Read/Write work area. As the disk rotates, the Index hole (sometimes referred to as the timing hole) tells the drive when one revolution is complete. Most drives use this as a timing device, telling the head to write another sector. The read/write notch works like the tabs on a cassette. When the disk is inserted into the disk drive, a microswitch "feels" for the read/write notch. If covered, the microswitch will not allow any writing to the disk. Write-protect tabs, either aluminum tape or masking tape, are available for this purpose. This prevents the information or program on the tape from being overwritten. If the tab is not present, the disk may be written to as well as read from.

Printers. A computer is limited only by its hardware capability and the program in it. Printers add greatly to the computer's capability. There are two main types of printers, the daisy wheel and the dot matrix.

Daisy wheel. The daisy wheel printer uses a wheel of characters that rotate and strike the paper for each character. Daisy wheel printers are relatively slow in comparison with dot matrix but produce the quality of print found on a typewriter. These are commonly referred to as letter quality printers.

Dot matrix. Dot matrix printers form characters by individual pins striking the paper. Since these pins can strike the paper in most any fashion desired, you are not limited by just the number of characters on a print wheel. Since the character is made up of dots, the typewriter quality is lost, but the dot matrix printer does not rely on a wheel to rotate, which means the time to print a page is much faster.

```
    *
  *   *
 *     *
*       *
* * * * *
*       *
*       *
```

Printers receive their information from the computer binary, in either a serial or a parallel fashion. Serial transmission has all bits going over one line to the printer with a start-stop bit to tell the printer the beginning and the end of a character. Parallel transmissions have all 8 bits going to the computer at once, which is obviously faster.

Plotter. An X, Y Plotter receives its information from the computer just like a printer. Using a pen, the letters are drawn, which is even more time consuming than a daisy wheel printer. However, since you now have the ability to draw, you can draw charts, graphs, or characteristic curves. This adds a lot of versatility to a computer system.

Exercises (057):

1. What is the main advantage of disks over tape?

2. What is a plotter used for?

3. Explain the difference between ROM and RAM.

4. What is the purpose for a keyboard on a computer?

5. Why would you have a monitor on a computer?

6. The term "letter quality" refers to what type of printer?

7. How does a floppy disk differ from a hard disk?

8. How would you prevent someone from writing to your floppy disk?

9. How are characters made with a dot matrix printer?

10. What is the main advantage the daisy wheel printer has over the dot matrix?

8-3. Operator Maintenance

As the operator of a computer system, like any system, you will be required to maintain some of the equipment from time to time. By maintenance, we don't mean opening the computer and troubleshooting. Quite simply, we are referring to cleaning, proper storage of media, and appropriate care of the equipment.

058. Given the elements of operator maintenance, explain their use and why.

Environment. All computer components are subject to static electricity and are extremely sensitive to dust. Since static electricity is often caused by carpets and clothing, special consideration should be given to the room the computer is in and the clothing worn by the operator. The equipment should be arranged to allow ease of use and a clean environment. Also, since the computer is sensitive to power fluctuations, it may be necessary to ensure that the operation of processing equipment does not interfere. This can be done by having a separate powerline just for the computer. It should also be noted that some computer equipment may require a cool environment to operate correctly. In this case you may also have to have air-conditioning installed.

Equipment Care. Care of the computer, keyboard, and monitor is mainly cleanliness. You should dust often with antistatic cloths, and never allow liquids near or in the computer area. One accident could cost thousands of dollars and considerable downtime. As a rule, the card cage requires no operator maintenance. The only exception would be if the card cage was not gold plated. Gold-plated cards do not oxidize, and therefore, contact is not a problem. However, if the card cage is not gold plated, it may be necessary to remove the oxidation from time to time.

Tape players/recorders require you to clean the heads from time to time and an occasional demagnetizing. Always refer to the TO or owner's manual for the equipment before attempting these operations as some procedures differ from machine to machine. Tapes should be stored in dust-free metal cabinets whenever possible. Being in metal cabinets will protect them from magnetic sources that might come near.

Hard disk drives require only external dusting and should never be opened by unqualified personnel. Floppy disk drives require occasional head cleaning to ensure proper data transfer. Usually a cleaning disk is inserted into the drive and operated for a minute or so. Refer to the TO or owner's manual for proper procedures for the equipment being used.

Floppy disks, like tape, are also sensitive to dust and magnetic fields. In addition, floppy disks should be stored vertically without pressure on the housing. Should a disk be stored horizontally with something on top, the housing could flatten, causing tension as the disk rotates which would interfere with the data transfer. This could also lead to the disk becoming scratched.

The writing surface is also very sensitive to dust, dirt, and fingerprints. Just touching the read/write hole could cause the disk to be unreadable. Since the floppy disk is so sensitive, backups are mandatory. Once a day's work on the computer is done, the information should be saved to at least 2 disks. Should a disk not want to load, the backup is always there.

Operator maintenance of printers normally consists of cleanliness and an occasional changing of the ribbon. Plotters are much like printers and should be treated the same. The pens of an X, Y plotter should be removed when not in use and the pen's cap be replaced. This will prevent the pens from drying up. Some plotter pens are refillable. Always refer to the TO or owner's manual for proper procedures.

Overall operator maintenance is nothing more than cleanliness and common sense. Knowing how a piece of equipment works will aid you in your ability to care for it properly. Always keep computer equipment clean and dust-free using dust covers. NEVER allow liquids or smoking in a computer room. An accident with a drink may cost thousands and cigarettes ashes become airborne and damage disks and equipment.

Exercises (058):

1. How should dusting of the computer equipment be accomplished?

2. Describe the proper storage method for floppy disks.

3. Briefly explain the procedures for caring for plotter pens.

4. Describe operator maintenance for hard disk drives.

5. Name two things all computer components are sensitive to.

6. What is the proper operator care for the keyboard?

7. Briefly explain the operator maintenance for a printer.

8. Describe the operator maintenance for a tape player.

9. When in doubt about the head cleaning procedures for a floppy disk drive, what should you do?

10. Why should smoke not be allowed in a computer room?

8-4. Computers in Reconnaissance

A computer system with proper programs can be a very useful tool in this career field. Computers can be used to plot and analyze characteristic curves and tone controls, trend analysis, machine certification, laboratory management, and much more.

059. List the four ways a computer system may be used in reconnaissance.

Characteristic Curves. By now you are familiar with the processing, reading, and plotting of a sensitometric strip. With a computer interface to the densitometer, as soon as the strip is read, the screen will show the graphic results. With the plotter, the results can be plotted on the graph paper along with necessary information such as developing speed, temperature, etc., and all in less than half the time it would take to do it manually.

Tone Controls. But this is just the beginning. Using the same graphing abilities, the all-day job of tone controls can be reduced to 2 or 3 hours, without the errors often made by making graphs by hand. Since a current tone control chart can be produced faster and with greater accuracy, they will be done more frequently, producing better quality tone reproductions.

Trend Analysis. Computers may be used also for trend analysis. Keeping hourly records of machine certification could help to determine the cause of a machine falling out of certification. These records can help pinpoint which workers are consistently having trouble with a processor, indicating the need for additional training.

Laboratory Management. As a management tool, the computer can help manage your schedules, maintenance records, OJT program, inventory, and tedious paperwork. Just one good database program can help you keep track of all missions processed, information about the mission, who worked on them, and many other important facts. The computer can be used to log in mission film and keep track of its progress through processing, editing, titling, and interpretation.

New uses for computers are being discovered daily. Using a modem, for example, will allow your computer system to talk with other computer systems via the telephone lines. This means any information available on your computer will be available to other bases worldwide. Say, for example, you need technical information on a type of chemistry that is new to your lab but another lab has been using it for several weeks. Instead of waiting days for the information to be sent to you through the mail, you can have it in your hands in minutes.

Overall, computers enhance our career field greatly and can be a manager's dream come true. They are limited only by their hardware capabilities, the programs available for given tasks, and trained individuals to operate them. Keep in mind that a computer will do only what it is told to do. If you're reading a strip on a densitometer, and the computer prompts you for step one, if you give it step 21 the results will be an un-certified processor. The saying of "garbage in - garbage out" applies. If you input garbage data, you will end up with garbage results.

Exercises (059):

1. What is an advantage of using a computer in tone control?

2. How can a characteristic curve be produced by a computer?

3. What can be determined by keeping hourly records of machine certification?

4. During trend analysis, how could you determine if additional training is needed for some of your personnel?

5. Name at least four ways a computer can be used in laboratory management.

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AFR 55–30, *Operations Security*.
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TO 00–5–1, *Air Force Technical Order System*.

Answers for Exercises

CHAPTER 1

Reference:
001 – 1. Satisfactorily performed in the 5-level AFSC for 6 months.
001 – 2. a, d, e, f.
001 – 3. Successfully completed all training requirements (this CDC is one of them).

002 – 1.
  a. E–5, 23350.
  b. E–9, 23100.
  c. E–3, 23330.
  d. E–7, 23370.
002 – 2. 3 level: E–1, -2, and -3; 5 level: E–2, -3, -4, and -5; 7 level: E–5, -6, and -7; 9 level: E–7 and -8.

003 – 1. 3 level.
003 – 2. 7 level.
003 – 3. 5 level.
004 – 1. b, d, and e.

CHAPTER 2

005 – 1. a, c.
005 – 2.
  (a) Shipping label attached to a case of 9.5-inch aerial duplicating film.
  (b) Mechanics of operating a unit, such as duty roster posted on bulletin board in unsecure area, transportation schedules, or dining hall operation orders in unsecure areas.

CHAPTER 3

006 – 1. b, c, d, and e.
006 – 2. A violent reaction occurs; heat is generated, and the solution boils and sputters.
006 – 3. Its corrosive nature.
006 – 4. Such articles as aprons, rubber gloves, and goggles.
006 – 5.
  a. Encourage cleanliness in operations involving skin contaminants.
  b. Clean up spills immediately.
  c. Provide adequate ventilation where harmful dusts, gases, vapor fumes, and mists may be produced.

007 – 1. Wear rubber gloves, rubber apron, and safety glasses.
007 – 2. Always add acid to water.
007 – 3. Intense heat is generated, dangerous fumes may result, and heat may cause evolution of steam and considerable splattering of hot acid.
007 – 4. A spark from the mixer may ignite the flammable vapor.
007 – 5. Chemical mix room should be well ventilated.

008 – 1. Yes. Exposes imagery production personnel to many of the accompanying hazards.
008 – 2. Poor judgement.
008 – 3. By maintaining an inspection schedule and conducting the inspections properly.

009 – 1. The new employee has demonstrated that he may not yet be familiar with the safety aspects of his duties. This is the time to give him additional training and observe how he responds.
009 – 2. This worker is disregarding specific instructions given to him by the supervisor. He should be disciplined immediately before he becomes involved in an accident.
009 – 3. There is no point in delaying the correction of a subordinate who is performing his duties in an unsafe manner. He should be corrected immediately.
009 – 4. In this situation, all formalities should be abandoned. Your first action is to render immediate help to the victim.
009 – 5. Inspect the equipment immediately for possible electrical hazards.

010 – 1.
  a. Poor work planning.
  b. Disregarding certain steps in local OIs.
  c. Mentally planning a vacation while operating a continuous processor.
010 – 2. a.
010 – 3. b.

011 – 1. The airmen failed to read the new machine's operating instructions.

012 – 1. Pressure and asphyxiation.

013 – 1. Ventilate the storage area.
013 – 2.
  a. Valves may be damaged.
  b. Physical injuries if the cylinder explodes.
  c. Require personnel to treat all cylinders as if they were filled.

014 – 1. Base ground safety and bioenvironmental engineering offices will assist the lab supervisor.
014 – 2. Prevent an injury from the stored electricity contained in the capacitor.
014 – 3. On a strong shelf with coping edges which prevent extending over the edge, or being shoved off the shelf.

015 – 1. (1) Training personnel in order to eliminate hazards, (2) making day-to-day observations, (3) conducting inspections, (4) making a job safety analysis, (5) establishing standards, (6) investigating and reporting accidents, (7) dealing with violations, and (8) maintaining an ongoing safety program.

016 – 1.
  a. False. Motivational methods are a major part of the safety program.
  b. True.
  c. True.
  d. False. You should assign firefighter duties to each person in the imagery production lab.
  e. True.
  f. False. Smoking receptacles should have lids.
  g. True.
016 – 2. Evaluation of your safety program.
016 – 3. These staff agencies give assistance in carrying out the imagery production lab safety and fire prevention program.

CHAPTER 4

017 – 1. a and c.
017 – 2.
  a. In the section entitled "Overhaul Instructions With Parts Breakdown" of the appropriate technical order.

b. In the section titled "Operations, Service, and Repair Instructions" of the applicable technical order.

018 – 1. a. 0–1–01 is a general index titled *Numerical Index and Requirement Table*. It is most often used to locate other indexes.
b. 0–2–1 is an alphabetical equipment list cross reference index.
c. 0–1–10, *Photographic Equipment, Supplies, and Sensitized Materials Technical Orders*. All photographic systems equipment technical manuals are listed in this index.

019 – 1. Time compliance technical orders.
019 – 2. Preliminary technical orders.
019 – 3. Methods and procedures technical orders.

020 – 1. You should have Technical Order 10E8–3–10–1, Operation and Service Instructions-Continuous Contact Printer, serial number 400 thru 503, type EN86A (Niagra Printer, EK P/N 1-008E001) (Eastman Kodak). (If you don't have the same information as that shown above, reread this portion of the text).
020 – 2. a. 10E8.
b. 10E8–3.
c. 10E8–3–8.
020 – 3. a. 10E8–3–8–1.
b. 10E8–3–8–3.
c. 10E8–3–4.
020 – 4. a. 10 indicates the category.
b. 10E indicates the major group.
c. 10E8 indicates the major subgroup.
d. 10E8–2 indicates a specific item.
e. 10E8–2–19 indicates a general series or equipment type, part, or model.
f. 10E8–2–19–4, the final digit, indicates the type of publication, whether it deals with operation and service instructions, etc.
021 – 1. Assign responsibilities, announce policies, direct actions, and prescribe procedures.

022 – 1. The customer account representative (CAR) is the person designated by each unit or staff office to be the official liaison between the unit and the publications distribution office. This person submits requirement for publications needed for the entire unit to PDO.
022 – 2. A functional publications library is a library of publications maintained at the unit or staff level which contains only those publications which are needed to perform the mission in the specific functional area.
022 – 3. An individual publications set is a set of publications maintained by an individual that are required references during the performance of his duties.

023 – 1. 5-1, 5-31, 12-32, 25-1, 35-10, 36-93.
023 – 2. File by number and type.
023 – 3. File the regulation first, the manual second, and the pamphlet last.
023 – 4. That the publication has been revised.
023 – 5. When you follow the directions on a change transmittal sheet by adding and removing pages or making minor changes, you are posting a change.
024 – 1. (1) Each task that must be done, (2) the reason for doing the task, (3) who is responsible for performing each task, (4) the procedure for doing each task, and (5) the authority for ordering each task.
024 – 2. To establish instructions for each situation.
024 – 3. 205–1.
024 – 4. There should be two OIs for each situation: one OI for each situation in the master set, and one in each location.

025 – 1. Mission failure and damage to equipment.

CHAPTER 5

026 – 1. Because the Earth and its inhabitants have only a limited supply of air and water.
026 – 2. Air and water.

027 – 1. a. Unless a permit is obtained, the Air Force is against such dumping because it violates the Refuse Act of 1899.
b. The Air Force is in favor of silver recovery, since it reduces waste and preserves a national resource.
c. The Air Force is against any action that is in violation of state law.
d. The Air Force policy aims at ensuring that oversea installations conform to the same abatement standards that are established in the United States. Discharging waste into a creek would be in violation here (without a permit) and the same should hold for an installation abroad.
e. The Air Force is in full coordination with all agencies concerned to avoid duplication. The cost of an incinerator would be quite expensive. With one already in use, it would be best to coordinate first with the Army to find a solution.

028 – 1. Physical damages in the form of scratches, abrasions, etc.
028 – 2. To preclude image degradations in the form of sharpness and detail.

029 – 1. Causes scratches or other abrasions.
029 – 2. The dust will resettle on the tacky rollers.
029 – 3. Corrosion.

030 – 1. Facility cleanliness has a definite influence on the cleanliness of the equipment used to produce the photographic products.
030 – 2. Dried chemicals can become airborne, settling on unprocessed photographic materials which will result in product discrepancies.

031 – 1. Airborne dust or dried chemicals settling on the unprocessed materials.
031 – 2. a. Dirt on the filters reduces effective illumination.
b. Dirt could also fall on sensitized materials creating defects.

032 – 1. a. Attached directly to the equipment.
b. Filed centrally in the maintenance shop.
032 – 2. a. Inspection schedule.
b. Discrepancies.
032 – 3. Red X, circled red X, red dash, and red diagonal.

033 – 1. E. Donovan, Amn, 09103, red X, Versamat drive shaft inop.
033 – 2. T. Mount, SRA, 22092, red X, wires arcing inside Mark IV R5A.
033 – 3. J. Huntington, Sgt, 22092, red dash, PE overdue.
033 – 4. T. Dewitt, AMN, 24122, red diagonal, speed control knob loose.

034 – 1. Never try to make repairs which require authorization, tools, or technical orders.
034 – 2. The nomenclature and ID number of the equipment, the location of the equipment, and a description of the discrepancy.
034 – 3. 0650006.

035 – 1. To assess the training and the trainee.
035 – 2. The ability of the graduates to perform assigned tasks of proficiency specified in the training standard; extent to which graduates use the acquired skills; extent to which graduates retain knowledge gained from the training; need to revise the training standard or school; and, the need for further evaluation of problem areas identified by evaluations.
035 – 3. Because of the need for sincere graduate responses to questionnaires.

036 – 1. Personnel from Air Force training activities who are training specialists. They are sometimes accompanied by career field specialists.
036 – 2. Because with face-to-face interviews, any confusion of questions asked can be cleared up immediately.
036 – 3. Upon completion of the last volume Review Exercise.
036 – 4. Commanders, first sergeants, supervisors, trainers, and graduates from any command.

CHAPTER 6

037 – 1. US customary and metric.
037 – 2. Meter.
037 – 3. 1,650, 763.73 wavelengths of the radiation produced by the Kr^{86} isotope of Krypton.
037 – 4. 1 meter = 39.37 inches.
038 – 1. a. 91.44 meters.
b. Left field - 98.15 meters.
c. Center field - 133.19 meters.
d. Right field - 109.73 meters.
038 – 2. 27.36 kilometers.

039 – 1. (1) Multiplication, (2) division, (3) addition, and (4) subtraction.

040 – 1. a. Digits other than zero are always significant.
b. A zero between two other significant digits is always significant.
c. When a number is less than 1, the zero between the decimal point and the first nonzero digit is not significant, but any zeros after the last nonzero digit are significant.
d. When a number is equal to or greater than 1 and is written with a decimal point, all zeros to the right of the last nonzero digit are significant.
040 – 2. a. Drop the remainder following the last digit which you wish to retain if the remainder is less than 5.
b. Raise the last digit to be retained if the remainder is greater than 5.
c. When the remainder is 5, round off so that the last retained digit is even.

041 – 1. a. $x = 14$.
b. $x = 13.91$.
c. $x = 17.5$.
d. $x = 1.5$.
e. $x = 9$.

041 – 2. a. 53.125 grams.
b. 82. 8125 grams.
c. 109.375 grams.
d. 190.625 grams.
e. 278.125 grams.
041 – 3. a. 10.56 feet.
b. 56.1 feet.
c. 46.1 feet.
d. 153.3 feet.
e. 93.9 feet.
041 – 4. a. 3.
b. 4.
c. 6.
d. 4.
e. 3.
041 – 5. a. 216.
b. 28,561.
c. 3,969.
d. 68,921.
e. 130,321.

041 – 6. a. $4\sqrt{3}$.
b. $7\sqrt{5}$.
c. $6\sqrt{3}$.
d. $5\sqrt{7}$.
e. $8\sqrt{3}$.

042 – 1. a. $3a - 10b$.
b. $-a - 4b$.
c. $-x + 8y + 6z$.
d. $5a - 2b$.
e. $-4a + 5c - d$.
f. $w + 7x - 10y - 6z$.
042 – 2. a. $x + 4y$.
b. $20a - b$.
c. $m + n$.
d. $10a + 2b - 3c$.
e. $14a - 6b + c + 9d$.
f. $4w - 6x + 9y + z$.
042 – 3. a. $-6a^2 - 8ab$.
b. $12a^2 - 6ab + 9ac$.
c. $10x^2 + 13xy - 3y^2$.
d. $-x^3 - x^2y - xy^2 + y^3$.
e. $3x^2 + 16xy - 8xz + 21y^2 - 20yz + 4z^2$.
042 – 4. a. $x - y$.
b. $a - b$.
c. $2a + 3b$.
d. $-2x - 2y$.
e. $a + b + c$.

043 – 1. a. When the number is greater than 1, the characteristic is positive and one less than the number of digits to the left of the decimal point.
b. When the number is less than 1, the characteristic is negative and is equal to one more than the number of zeros immediately to the right of the decimal point.
043 – 2. It is determined from a table of common logarithms, using interpolation if necessary.
043 – 3. The reverse procedure for determining the logarithm.
043 – 4. Interpolation is required when changing a four or more digit number to logarithmic form, and when the mantissa cannot be found in the body of the log table during antilogarithm determination.
043 – 5. 8.

044 – 1. a. 4.4316; 27,010.
b. 1.8042; 63.71.
c. 1.9916; 98.08.
d. 6.6562; 4,531,000.

044 – 2. a. 1.8129; 65.
b. 2.2183; 165.3.
c. $\bar{5}.9616$; 0.00009154.
d. 0.2382; 1.731.

CHAPTER 7

045 – 1. The capability to process, print, and interpret information gained through tactical reconnaissance operations.
045 – 2. a. The expandable interpretation lab, ES-64A, provides support of normal tactical interpretation functions.
b. The series I printing, ES-57D shelter, provides both continuous and step and repeat printings. The ES-58D shelter has the capability of producing projection print.
c. The series III printing, ES-73A shelter utilizes a Niagara Continuous contact printer to produce high-speed continuous printing.
d. The chemical mixing and distribution lab, ES-65A, provides a capability for mixing, temporary storage, and transferring of solutions.
045 – 3. The NCOIC is responsible for supervising all portions of a mobility exercise or actual deployment. He reviews all procedures and checklists for accuracy, completeness, and compliance with directives. He also coordinates all deployment activities and resolves problems.

046 – 1. Maintenance personnel.
046 – 2. Cleaning, draining, disconnecting, inspection, and stowing and securing.

046 – 3. Maintenance personnel will shut down the power, disconnect, inspect, and cap the power cables. Then designated PPIF personnel will stow and secure the cables.
046 – 4. Each shelter has a list and a storage diagram of the equipment stowed within that particular shelter. This information is taken from the TO for the particular shelter.

047 – 1. Install a brace on each end of the metal base. Compress the 17 poles and place lengthwise on passageway base. Fold the blanket and strap on top of passageway base.
047 – 2. At the air conditioner end of the van.
047 – 3. The solution lines are wrapped around posts screwed into the floor (and in some cases the ceiling) of the shelter.

048 – 1. The developer remaining in the chemical system will contaminate the new type developer. Therefore, it will not certify. If it is used without certifying, results will not be predictable.
048 – 2.
   a. The system cleaner remaining in the system will contaminate the new developer.
   b. Dichroic fog will be formed on the film.
048 – 3. If the temperature during transport reached freezing levels, the water in the pipes and lines probably froze. If this happened, many of these pipes and lines will have to be replaced before the facility will be operational.

049 – 1. To ensure that all the shelters are the same height.
049 – 2. 3.
049 – 3. The air line and manifold assembly regulate the pressure. If the lines are for transferring chemistry, a psi of 20 is needed, and if the system is used to purge, a psi of 40 is needed.

050 – 1. List any 10 of the following.
   a. Ensure all circuit breakers are off.
   b. Remove facility-stored equipment.
   c. Prepare air-conditioner for use.
   d. Remove tiedowns and padding from processor Model 11 C-MW. Install roll takeup and roll adapters on processor.
   e. Prepare sensitometer for use.
   f. Prepare maintenance kit for use.
   g. Prepare processor B-5A for use.
   h. Prepare silver recovery system for use.
   i. Prepare plumbing system for use.
   j. Prepare electrical system for use.
   k. Connect intercom.
   l. Perform miscellaneous checks.

051 – 1. a, c, and d.
051 – 2. Improper rack and crossover placement and incorrect processor leveling.

052 – 1. Shelter relocation. In this instance, probable stresses produced during transport can be blamed for the warped roller rack. In a fixed facility, normal maintenance practices should preclude any such event from happening.
052 – 2. Shelter relocation. Again, shelter relocation is the best answer because of disconnecting the chemical lines for transport. True, these lines should have been purged before use, but the possibility of missing such a task is greater than the accumulation of this foreign matter in the chemical lines in a fixed facility.
052 – 3. Normal circumstances.

053 – 1. The materials might be nearing or past their expiration date. If the date has not passed, those nearest the expiration date must be used first. Also, material stored in shelters where the temperature has risen above maximum safe level during transport can be salvaged many times if it is used first.
053 – 2. If processors are not anchored properly, they might have shifted positions during transport. This could result in the loading end not being light tight.
053 – 3. Damage to expansion laboratories could render them extremely difficult, if not impossible, to expand.

054 – 1. Production Control and Quality Control.
054 – 2. AFTO Forms 349 and 244.
054 – 3. A check conducted to ensure that any potential problem can be identified and corrected before it stops the production aspect of the facility.

CHAPTER 8

055 – 1. Binary.
055 – 2. 1, 2, 3, 4, 5, 6, 7, 8, 9, 0.
055 – 3. Computers only deal with two numbers, 1 and 0.
055 – 4. When writing programs with an assembler, when debugging a program with some operating systems, and when writing some BASIC programs.

056 – 1. Assembly language is much faster than BASIC.
056 – 2. BASIC language is much simpler and easier to learn.
056 – 3. The computer must be interpreted into machine language before it can be executed.
056 – 4. Machine language is made up of binary numbers that the computer will recognize.

057 – 1. Disks are easier to store and hold more data.
057 – 2. A plotter is used to draw charts, graphs, etc.
057 – 3. ROM means read only memory and can not be written to; RAM means random access memory and can be read as well as written to.
057 – 4. The keyboard is used to enter information into the computer.
057 – 5. The monitor lets you see what the computer is doing as well as a means for the computer to communicate with you.
057 – 6. A letter quality printer has a daisy wheel to make the characters and is equivalent to the typewriter.
057 – 7. A floppy disk is smaller than a hard disk and is removed from the computer when not in use.
057 – 8. By covering the read/write notch.
057 – 9. The characters on a dot matrix printer are made by a pin striking the paper in the pattern of the character.
057 – 10. Speed of printing.

058 – 1. With a static-free cloth.
058 – 2. Floppy disks should be stored vertically with no pressure on the housing.
058 – 3. Plotter pens should be removed from the plotter and thoroughly cleaned when not in use.
058 – 4. No maintenance normally is required of the hard disk.
058 – 5. Dust and magnetism.
058 – 6. The keyboard should be dusted with a static-free cloth and all foreign materials such as food, drinks must never be allowed in the computer area.
058 – 7. The printer should be kept clean and occasionally the ribbon will need changing.
058 – 8. Tape players are to be dusted. Any maintenance done should be by a qualified person and by the appropriate manual.
058 – 9. Always consult the TO or owner's manual.
058 – 10. Smoke carries dust into the computer components.

059 – 1. Computers can evaluate Tone control data much faster than people and more tone controls can be made in a day's time.
059 – 2. The information can be entered directly from the densitometer and a plotter can construct the curve for you.
059 – 3. Hourly records can determine the cause if the machine should fall out of certification.
059 – 4. Trend analysis can determine if one person might be having trouble with a processor.
059 – 5. In constructing characteristic curves, tone controls, trend analysis, and laboratory management.

STOP-

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 01 23

GENERAL SUBJECTS FOR IMAGERY

PRODUCTION SPECIALIST

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (001) Which of the following qualifications is *mandatory* for the award of AFSC 23350?
   - a. Completion of high school with courses in chemistry and computer science.
   - b. Knowledge of elementary electronics.
   - c. Knowledge of video film transfer.
   - d. Minimum ASVAB score of Mechanical 40.

2. (002) What ranks are eligible for the award of AFSC 23399, Imagery Production Superintendent?
   - a. Technical and master sergeant only.
   - b. Master and senior master sergeant only.
   - c. Senior master and chief master sergeant.
   - d. Master, senior master, and chief master sergeant.

3. (003) As a 5-level imagery production specialist, one of your duties is to
   - a. schedule classified work assignments.
   - b. establish production control procedures.
   - c. conduct on-the-job training.
   - d. establish work priorities.

4. (004) At what skill level would airmen be responsible for planning and scheduling work assignments and priorities?
   - a. 3 level.
   - b. 5 level.
   - c. 7 level.
   - d. All skill levels.

5. (005) An example of an *operations* vulnerability for the 233X0 career field would be
   - a. letting everyone go home if the mission is aborted.
   - b. a shipping label attached to a case of 9.5-inch aerial film.
   - c. describing a classified product over the phone.
   - d. posting the duty roster in an unsecure area.

6. (006) If you add water to any strong acid, the reaction will be
   - a. violent.
   - b. in the form of sediment.
   - c. mild.
   - d. in the form of discoloration.

7. (006) Mixing an acid with a cyanide produces
   - a. caustic potash.
   - b. a lethal gas.
   - c. excess moisture in the air.
   - d. sulfuric acid.

8. (007) A chemical mixing area should be
   - a. cleaned with potassium hydroxide.
   - b. sprayed with teflon.
   - c. well ventilated.
   - d. contamination-free.

9. (007) If contact of the skin with mercuric chloride is prolonged, vomiting will occur within
   - a. 10 to 15 minutes.
   - b. 5 to 10 minutes.
   - c. 3 to 5 minutes.
   - d. 1 to 3 minutes.

10. (008) Which of the following is generally associated with all electrical accidents?
    - a. Improper input.
    - b. Short circuits.
    - c. Accidental grounding.
    - d. Human error.

11. (009) If heart muscles contract spasmodically as a result of electric shock, death may result if the shock victim is *not* released from the current source within
    - a. one minute.
    - b. three minutes.
    - c. six minutes.
    - d. nine minutes.

12. (009) What is the body response to a current flow of 5 to 15 milliamperes (ma)?
    - a. Instant death.
    - b. Stimulation of the muscles.
    - c. Permanent damage to blood vessels.
    - d. Paralysis of the breathing nerve center.

13. (010) The *most* important thing to learn about a new piece of equipment other than operation is

a. the cost.
b. production rate.
c. its place in the lab.
d. the safety features.

14. (010) Work planning is important to mechanical safety because it

a. helps reduce unsafe motions.
b. increases the number of operations.
c. maximizes mistakes.
d. minimizes good discipline.

15. (010) To avoid accidents, alertness is important

a. at all times.
b. when learning new procedures.
c. while your supervisor is close by.
d. toward the end of the day.

16. (010) Which of the following is *not* normally associated with physical distractions?

a. Fatigue.
b. Daydreaming.
c. Illness.
d. Severe pain.

17. (011) When you receive a modified piece of equipment, what should you do *first*?

a. Plug it in to see if it is operational.
b. Read the applicable TO or instruction manual.
c. Perform a trial operation while the supply delivery people are present.
d. Change the number on the old TO to correspond to the modified equipment.

18. (012) The degree of hazards in pressure systems is proportional to

a. the amount of pressure present.
b. the amount of energy stored.
c. the room temperature.
d. the amount of dilution.

19. (012) Compressed nitrogen gas is considered to be

a. chemically inert.
b. explosive.
c. flammable.
d. toxic.

20. (013) Cracking the valve on a cylinder of nitrogen gas serves what purpose?

a. Reduces pressure.
b. Clears the valve of particles which would otherwise enter the regulator.
c. Throttles the cylinder valve, causing the proper pressurization.
d. Decompresses the gas.

21. (013) Nitrogen is classified by the ICC as a nonflammable gas and requires what color label for shipping?

a. Red.
b. Yellow.
c. Blue.
d. Green.

22. (014) Chemicals which react violently with each other should be stored

a. separately.
b. on a strong shelf.
c. on the bottom shelf.
d. on a shelf that has a ledge.

23. (014) How many hours should be allowed for the safety bleeder to deplete the charge before permitting the removal of a broken tube from strobe equipment?

a. At least 2.
b. At least 12.
c. At least 24.
d. At least 72.

24. (015) Which choice presents three of the eight supervisory responsibilities in establishing and evaluating a safety program?

a. Paying attention to details, using up-to-date methods, and making daily inspections.
b. Dealing with violations, making a job safety analysis, and conducting frequent counseling sessions.
c. Establishing standards, making day-to-day observations, and listening carefully.
d. Conducting inspections, establishing standards, and dealing with violations.

25. (015) After you have established a safety program, what must you do to ensure that it is effective?

   a. Make your subordinates responsible to carry out your program.
   b. Train all personnel to recognize failures and hazards.
   c. Evaluate your program by using meaningful inspection procedures.
   d. Analyze each laboratory job to see if safe working conditions exist.

26. (016) Where should you put a safety poster dealing with wet, slippery floors?

   a. In the printing area.
   b. At the front entrance.
   c. By the work order desk.
   d. In the chemical mixing area.

27. (016) When a safety program is inadequate, it can usually be traced to the failure of what two things?

   a. Motivation and training.
   b. Supervision and evaluation.
   c. Analysis and instruction.
   d. Timeliness and recognition.

28. (017) Which of the following is *not* normally found in a technical order manual?

   a. Equipment operation.
   b. Equipment cost.
   c. Maintenance procedures.
   d. Parts identification.

29. (017) Which part of a technical order manual provides information on identification and requisition of a new part?

   a. Operating Instructions.
   b. Operation, Service, and Repair Instructions.
   c. Overhaul Instructions with Parts Breakdown.
   d. Overhaul Instructions.

30. (018) Which listed technical order is considered the index to indexes?

   a. TO 0-1-01.
   b. TO 0-1-2C.
   c. TO 0-1-8E.
   d. TO 0-1-10.

31. (018) In which technical order would you find information on photographic supplies?

   a. TO 0-1-10.
   b. TO 0-1-11.
   c. TO 0-1-12.
   d. TO 0-1-13.

32. (019) Time compliance technical orders (TCTOs) provide instructions for

   a. procurement of equipment within a certain time frame.
   b. making a one-time change to equipment in or out of service.
   c. requesting a change to a basic tech order series.
   d. scheduling inspections of photographic equipment.

33. (019) The identification number of methods and procedures technical orders begins with

   a. 00.
   b. 11.
   c. 22.
   d. 33.

34. (020) Which of the following numbers identifies a major group of technical order publications with *no further breakdown*?

   a. 10.
   b. 10E.
   c. 10E8.
   d. 10E8-2.

35. (020) Which part of the Technical Order number 10E8-2-19-4 is used to identify an illustrated parts breakdown?

   a. 10E8.
   b. -2.
   c. -4.
   d. -19.

36. (020) Which of the following major groups of publications has as its title "Photographic Laboratories"?

   a. 10A.
   b. 10E.
   c. 10J.
   d. 10M.

37. (020) Which of the following major groups would you use to find sensitized materials and supplies?

a. 10J.
b. 10K.
c. 10L.
d. 10M.

38. (021) What is the purpose of Air Force regulations?

a. To ensure that each job is done timely and uniformly.
b. To direct actions and prescribe procedures.
c. To ensure that everyone performs his or her job the same.
d. To ensure that each job is done properly and uniformly.

39. (021) What are the primary administrative publications that govern the Air Force?

a. Regulations.
b. Operating instructions.
c. Special operating instructions.
d. Technical operating instructions.

40. (022) Who is initially contacted when requesting a new publication for an individual publications set?

a. Publications distribution office (PDO).
b. Customer account representative.
c. Squadron orderly room clerk.
d. Master publications librarian.

41. (022) Define *master publications library*.

a. A centralized repository of standard and specialized publications.
b. The unit or staff office file which contains only those publications which are needed to perform the mission in a specific area.
c. A single publication or group of publications that relate directly to the duties of the holding individual.
d. Technical and administrative publications that apply directly to the daily operation of the user.

42. (023) Which of the following sequences for filing publications is correct?

a. Numerically, level of command.
b. Alphabetically by command only.
c. Chronologically, level of command.
d. Numerically only.

43. (023) How are supplements to publications filed?

a. In separate binders.
b. Behind the applicable publication.
c. In front of the applicable publication.
d. Insert after each page supplemented.

44. (024) Which type of publication clearly outlines job responsibilities within the work section?

a. Air Force regulations.
b. Supplements to Air Force regulations.
c. Base regulations.
d. Operating instructions.

45. (024) What does operating instruction numbered 95-4 indicate?

a. Supply procedures, fourth in the series.
b. Imagery production systems, Titling section.
c. Audiovisual systems, fourth in the series.
d. Publications Management, Processing Correspondence.

46. (025) A commercial technical publication on equipment will contain all of the following information *except*

a. cost.
b. installation.
c. operation.
d. assembly.

47. (025) Concerning the use of commercial publications, information on expendable type supplies is found in

a. technical orders.
b. single-page bulletins.
c. technical manuals.
d. operating instructions.

48. (026) Environmental pollution is an economic, technical, and social problem concerned with

a. the earth's resources of air and water.
b. radiation effects from outer space.
c. de-salinization of sea water.
d. silver resources.

49. (027) According to the text, allowing virtually any substance other than sewage to be discharged into a river without a permit is in violation of

a. state regulations.
b. the Refuse Act of 1899.
c. local regulations.
d. the Environmental Protection Act.

50. (027) For the control and abatement of air pollution, the Clean Air Act requires all Air Force installations to comply with

a. only Federal regulations.
b. only state regulations.
c. Federal, state, interstate, and local requirements.
d. ordinances of the city closest to base.

51. (027) The dumping of photographic fixer into a sewer is considered pollution if the fixer contains silver in quanities above

a. two parts per million.
b. three parts per million.
c. four parts per million.
d. five parts per million.

52. (028) Which of the following is *not* caused by the equipment physically damaging the photographic material?

a. Scratches.
b. Pinholes.
c. Decreased detail.
d. Creases.

53. (028) Contamination of the solution used in the photographic process can result in the loss of all of the following *except*

a. contrast.
b. density.
c. exposure.
d. material sensitivity.

54. (029) If allowed to get dirty, what part(s) of the continuous film processor will result in the greatest number of physical defects?

a. Solution tanks.
b. Magazine.
c. Temperature control units.
d. Transport rollers.

55. (030) Which of the following would *not* be a benefit derived from laboratory cleanliness?

a. Defect-free products.
b. Corrosion-free equipment.
c. Dust-free equipment.
d. Airborne dried chemicals.

56. (031) When cleaning an imagery production facility, you should *not*

a. flood the tile floors with water.
b. rinse and wring the mop out frequently.
c. use the vacuum when cleaning the floor.
d. remove dirt from safelights with a damp sponge.

57. (032) Select the three most commonly used equipment maintenance forms.

a. AFTO 244, AFTO 95, and AFTO 246.
b. AFTO 244, AFTO 245, and AFTO 246.
c. AFTO 244, AFTO 95, and AFTO 245.
d. AFTO 244, AFTO 95, and AFTO 247.

58. (032) A red X discrepancy symbol tells the operator that

a. the equipment is considered unsafe.
b. the equipment condition is unknown.
c. an unsatisfactory condition exists.
d. a periodic inspection is overdue.

59. (033) The Inspection Record, Part III of AFTO Form 244, indicates

a. the daily service inspections.
b. if anything is wrong with the equipment.
c. quality control or supervisory review of the equipment.
d. the next scheduled PE.

60. (033) Since the directives governing the entries to be made on AFTO forms change from time to time, it is a good idea to check the latest edition of

a. TO 00-20-1.
b. TO 00-20-2.
c. TO 00-20-7.
d. TO 00-21-1.

61. (034) What is the first step to take when reporting equipment discrepancies?

a. Turn off machine.
b. Notify the maintenance section of your location.
c. Place down sign on the equipment.
d. Notify the maintenance section of the problem.

62. (034) Maintenance action is *not* authorized without

a. a job control number assigned to the discrepancy.
b. a five-digit job control number.
c. a five-digit job control number assigned to the discrepancy.
d. approval of your section supervisor.

63. (035) Who participates in the USAF Graduate Evaluation Program?

a. Air Force supervisors of course graduates only.
b. Course graduates only.
c. Both Air Force supervisors of course graduates and the graduates themselves.
d. OJT trainers and course graduates.

64. (035) What is the purpose of the USAF Graduate Evaluation Program?

a. To evaluate the effectiveness of career development courses only.
b. To evaluate the effectiveness of formal resident courses only.
c. To evaluate the effectiveness of both career development courses and formal resident courses.
d. To evaluate the effectiveness of on-the-job training.

65. (036) Concerning the Air Force Graduate Evaluation Program, within what period of time after graduates have been assigned are field evaluations visits made?

a. One year.
b. Six months.
c. Three months.
d. One month.

66. (036) Select the *best* method of performing graduate evaluations.

a. Job performance evaluations.
b. Field evaluation visits.
c. Direct correspondence questionnaries.
d. AF Form 1284, Training Quality Report.

67. (037) What is the measure of length in the metric system?

a. Yard.
b. Foot.
c. Meter.
d. Inch.

68. (037) The length of the meter has officially been established as

a. 32.35 inches.
b. 35.32 inches.
c. 37.39 inches.
d. 39.37 inches.

69. (038) Converting measurements in one system to another system (meters to inches or inches to meters) is a matter of

a. addition.
b. addition or division.
c. multiplication.
d. multiplication or division.

70. (038) Determine the number of feet in two kilometers.

a. 65.6166.
b. 787.4.
c. 6561.66.
d. 78740.

71. (039) The order of the rule of precedence in solving mathematical problems is

a. add, subtract, multiply, and divide.
b. subtract, multiply, divide, and add.
c. multiply, divide, add, and subtract.
d. divide, add, subtract, and multiply.

72. (040) The number 23.85 when rounded off to the nearest tenth has a value of

a. 23.
b. 23.8.
c. 23.9.
d. 24.

73. (040) Which of the following numbers contains four significant figures?

a. 0.055.
b. 0.0660.
c. 0.07700.
d. 1.06900.

74. (041) What percentage of light will be transmitted through a gray scale if the incident illuminance is 60 meter candles and transmitted illuminance is 20 meter candles?

a. 60 percent.
b. 33 percent.
c. 30 percent.
d. 20 percent.

75. (041) To what power must the number 7 be raised to equal 343?

a. First.
b. Second.
c. Third.
d. Fourth.

76. (041) If a number such as 25 is expressed as 5 times 5, the number 5 can then be termed the

a. exponent of 5.
b. negative exponent.
c. standard deviation.
d. square root of 25.

77. (041) The square root of x can be expressed as

a. an infinite exponent.
b. $x^{1/2}$.
c. x^2.
d. $(x^{1/2})(x^{1/2})$.

78. (042) If you subtract $x^3 - 2x^2y + 3xy^2$ from $3x^3 - 4x^2y - xy^2 + 2y^3$, the result is

a. $4x^3 - 6x^2y + 2xy^2 + 2y^2$.
b. $4x^3 - 6x^2y + 2xy^2 - 2y^2$.
c. $2x^3 - 2x^2y - 4xy^2 - 2y^2$.
d. $2x^3 - 2x^2y - 4xy^2 + 2y^3$.

79. (042) In algebraic multiplication, 2 times minus 4 times minus 2 times 6 equals

a. 0.
b. 2.
c. -96.
d. 96.

80. (042) When you multiply one polynomial by another polynomial,

a. the exponents are multiplied, as example, $a^2 \times a^3 = 6$.
b. each multiplicand term is multiplied by each multiplier term.
c. the sign of each term in the multiplier is changed.
d. the coefficient of the various terms are added.

81. (042) The expression $2x^2 - 4x + 8x^3$ when divided by 2x equals

a. $x^3 - 2x^2 + 4x^4$.
b. $2x - 4 + 8x^2$.
c. $x - 2 + 4x^2$.
d. $4x - 6 + 10x^2$.

82. (043) What is the characteristic of the logarithm of the number 234?

a. 1.
b. 2.
c. 3.
d. 4.

83. (043) The log of 234 has a mantissa of .3692. What is the mantissa of the log of 2.34?

a. .3692.
b. 3.692.
c. 36.92.
d. 369.2

84. (043) The number that corresponds to a given logarithm is called the

a. characteristic.
b. mantissa.
c. antilogarithm.
d. negative characteristic.

85. (044) When you add the logs of three numbers and find the antilog of the sum, what are you doing to the original numbers?

a. Squaring.
b. Multiplying.
c. Dividing.
d. Adding.

86. (044) When you subtract the log of one number from the log of another, and find the antilog of the difference, what are you doing to the original numbers?

a. Adding.
b. Dividing.
c. Multiplying.
d. Squaring.

87. (045) The basic function of a WS-430B is to

a. be deployed in the daytime only.
b. process and print film for the base photo lab.
c. be deployed each time as a whole unit.
d. process and interpret tactical reconnaissance imagery.

88. (045) The ES 57-D shelter provides

a. continuous and step-and-repeat printing.
b. projection printing.
c. high speed continuous printing.
d. film titling and cleaning.

89. (046) Where is the checklist and inventory list kept for mobilizing the WS-430B?

a. In the TO file in maintenance.
b. On the door of each shelter.
c. In the mobility tool kit.
d. The final inspector has it.

90. (047) Which choice *best* states the parts of a shelter passageway?

a. A blanket, base, fabric cover, and support rods.
b. A blanket, base strings, and support rods.
c. A blanket, base, support rods, and zippers.
d. A blanket, base, bridge, and a cover.

91. (048) Purging the chemical supply lines is absolutely required *except* when

a. the facility is located in a cold climate and power is not available to operate the water and drain-line heaters during shutdown periods.
b. rail transporting the facility in a tropical climate.
c. air transporting the facility during summer months.
d. changing from one type chemistry to another.

92. (048) What air pressure is used to purge the chemical supply lines of a WS-430B?

a. 40 psi.
b. 30 psi.
c. 20 psi.
d. 10 psi.

93. (048) The very *first* thing that should be done when draining the Argenta Model 105 silver recovery unit is to

a. drain the filter-flowmeter.
b. drain both silver recovery tanks.
c. disconnect the unit from its power source.
d. remove the reclaimation cathode.

94. (049) When should the passageway be installed?

a. After the shelters are leveled and after the lines are connected.
b. Before the shelters are leveled and after the lines are connected.
c. After the shelters are leveled and before the lins are connected.
d. Before the shelters are leveled and before the lines are installed.

95. (049) A full PPIF complex will contain

a. one generator.
b. three generators.
c. four generators.
d. six generators.

96. (050) What is the *first* step in preparing the ES-59A laboratory for use?

a. Remove tie-downs and padding.
b. Install silver recovery system.
c. Ensure that all circuit breakers are turned OFF.
d. Ensure that all circuit breakers are turned ON.

97. (050) Which of the following would *not* be considered a preuse preparation task for the ES-59A shelter?

a. Prepare sensitometer for use.
b. Prepare densitometer for use.
c. Prepare B-5A processor for use.
d. Prepare air conditioning unit for use.

98. (051) Which of the following statements concerning preuse preparation of the processor is true?

a. After the preuse preparation tasks have been completed, the processor is ready for processing mission film.
b. If the tie rods, brackets, anchors, etc., were properly used, the processor cannot be physically damaged during transport.
c. The processor must be charged with chemicals and certified before processing mission material.
d. All six tie rods must be removed from the processor before it can be used.

99. (051) Which of the negative characteristics listed below would *not* be related to improper processor preparation?

a. Crimped edges.
b. Fog.
c. Abrasions.
d. Excessive density.

100. (052) Which of the following undersirable characteristics encountered during initial certification of a relocated processor would be caused by normal circumstances, rather than by shelter relocation?

a. Decreasing gama resulting from foreign matter retarding the replenisher flow.
b. Fog caused by light leaking from around the air conditioner.
c. Inoperative recirculation pump.
d. Material wraparound caused by a warped roller.

101. (053) What is the *first* thing that must be done after positioning the shelters?

a. Install the water and drain lines.
b. Inspect each shelter and its contents.
c. Connect the communication cables.
d. Lay the power cables.

102. (054) Responsibility for ensuring that each piece of equipment is certified on a timely basis belongs to

a. supervisors.
b. equipment operators.
c. maintenance personnel.
d. production control and quality control.

103. (054) Which of the following is *not* considered preventive maintenance?

a. Inspecting and updating photo sensitive materials.
b. Removing minor corrosion from chemical storage tanks.
c. Adjusting the water pressure in each shelter.
d. Removing a minor scratch-producing problem from the versamat.

104. (055) The most common numbering system used in computer languages is the

a. binary system.
b. decimal system.
c. hexadecimal system.
d. microdecimal system.

105. (056) A machine language is

a. a language that robots speak.
b. a hexidecimal interpretation of computer instructions.
c. a binary interpretation of computer instructions.
d. the noise a processing machine makes while operating.

106. (056) What is the biggest disadvantage of BASIC?

a. It is too fast for the computer.
b. It cannot be used for mathematics.
c. It has to be written in assembly language first.
d. It is very slow for loading programs into the computer.

107. (057) The computer keyboard is

a. the user's means of communicating with the computer.
b. the computer's means of communicating with the user.
c. a method of expanding the capability of the computer.
d. the device used to store the information prior to turning off the computer.

108. (057) A computer monitor is the

a. device used to store the data in the computer.
b. means of inputting information to the computer.
c. person designated to watch the computer system.
d. device used to display the data from the computer.

109. (058) Operator maintenance of computer equipment should be performed

a. only by senior operators.
b. in the equipment maintenance shop.
c. by the shop's maintenance personnel.
d. in accordance with applicable publications.

110. (058) Floppy disks should be stored

a. vertically, with no pressure on the housing.
b. horizontally, with no pressure on the housing.
c. vertically, with slight pressure on the housing.
d. horizontally, with slight pressure on the housing.

111. (059) Which of the following statements about computers is correct?

a. They are always more effective than people.
b. They serve no apparent use in the laboratory.
c. They have little application in reconnaissance.
d. They are only as effective as the information placed in them.

112. (059) Tone control with a computer

a. can only be accomplished once a day.
b. cannot be used in machine certification.
c. can be accomplished as quickly as by hand.
d. can be accomplished much faster than by hand.

END OF EXERCISE

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PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package, and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

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1. THIS REQUEST CONCERNS COURSE (1-6)
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3. ENROLLMENT DATE
4. AUTOVON NUMBER
5. SOCIAL SECURITY NUMBER (7-15) ☐☐☐ – ☐☐ – ☐☐☐☐
6. GRADE/RANK
7. NAME (First initial, second initial, last name) (17) – (18) – (19-32)
8. ADDRESS (33-53) (54-75)
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ALL OTHERS: Current mailing address with zip code.
9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE
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2 Request Test Control Office change as indicated in Section I, Block 10.
3 Request name change/correction. *(Provide Old or Incorrect data here)*
4 Request Grade/Rank change/correction.
5 Correct SSAN. *(List incorrect SSAN here.)* *(Correct SSAN should be shown in Section I.)*
6 Extend course completion date. *(Justify in "Remarks")*
7 Request enrollment cancellation. *(Justify in "Remarks")*
8 Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 10
Originals were: [ ] Not received [ ] Lost [ ] Misused
9 Send course materials. *(Specify in "Remarks")*
[ ] Not received [ ] Lost [ ] Damaged
10 Course exam not yet received. Final VRE submitted for grading on ____________ (date).
11 Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received.
Answer sheet(s) submitted ______________ (date).
12 Results for CE not yet received. Answer sheet submitted to ECI on ____________ (date).
13 Previous inquiry ([ ] ECI Fm 17, [ ] ltr, [ ] msg) sent to ECI on ____________ (date).
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15 Other *(Explain fully in "Remarks")*

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P	VOL 33-35	
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	MC 39-42	

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CDC 23350

IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

Volume 2

Photographic Fundamentals

Extension Course Institute
Air University

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Preface

THIS SECOND volume of CDC 23350, *Imagery Production Specialist*, is a review of photographic fundamentals. The photographic principles and procedures discussed in this volume establish the basis for the advanced procedures discussed in Volume 3. Chapter 1, titled *Photographic Principles*, covers light, optics, aerial sensors, both black-and-white and color film emulsions, print materials, and solutions. Chapter 2 deals with producing black-and-white and color imagery manually. This includes the setup of the laboratory, selection of printing material, the printing, processing, and finishing of the material, and shut down of the lab. Chapter 3 covers the fundamentals of black-and-white and color reproduction photography. This includes corrective techniques, proper use of scales, exposure determination, and finishing techniques.

Code numbers appearing on figures are for preparing agency identification only.

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This volume is valued at 57 hours (19 points).

Material in this volume is technically accurate, adequate, and current as of March 85.

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CHAPTER 1

Photographic Principles

THE WORD "photography" is derived from two Greek words that translate to "making pictures with light." Light is defined as "visible radiant energy." It is a form of energy that causes physical and chemical changes in substances. Particles, rays, and waves are all terms used to describe the action of light, but light is unlike any one word that has been used to describe it. To speak of light as a particle, ray, or wave is merely to illustrate how it acts under certain conditions. Light is simply light, and calling it one thing as opposed to another is only a matter of convenience. Photography is possible only through the use of light; therefore, it is important that you understand its basic principles.

1-1. Theory of Light

Exactly what is light? No one knows for certain. Although there are several theories, the most acceptable one for our purpose is the *wave front theory*. In simple terms, the wave front theory proposes that each infinitely small point (millions of which could be found on an area as small as the head of a common pin) will radiate a wave front. This would be true whether the point were part of the source, such as the sun or a lamp, or were part of an object that reflected light. Such an infinitely small point source radiates a wave front almost the same way waves radiate outward on the smooth surface of water when a peeble is dropped in a pool.

200. Define basic terms associated with the nature of light.

Nature of Light. Light is a form of radiant energy that travels in all directions from its source. By radiant energy, we mean any form of energy radiating from a source, such as electromagnetic waves, sound, heat, light, X-rays, and gamma rays. Like other forms of radiant energy, light travels in waves of varying lengths. The wavelength of the light determines its color, and it is measured as the distance between corresponding parts of two consecutive waves, as shown in figure 1-1.

The direction of the wave front (wave front being the radiation of waves similar to our pebble-in-the-pool example) is represented by a straight line in practically all optical diagrams, such as those showing the functioning of a lens. This straight line represents the radius of the wave front radiating from the point source. It is commonly termed as a "ray" of light.

Another term that describes light waves is "frequency." Frequency of light is the number of waves that pass a fixed point in a given unit of time. If you drop a pebble in a pool of water, waves radiate out from the point where the pebble entered the water. If you pick a certain point on the surface of the pool and count the number of waves passing that point during a period of, for example, 10 seconds, you can establish a frequency of sorts.

Although a human eye can see visible radiant energy, it cannot see the other portions of the spectrum such as radio, X-ray, gamma, etc. For this reason the term "light" is generally restricted to the part of the total electromagnetic spectrum that the human eye can see. The upper part of figure 1-2 shows you the entire electromagnetic spectrum. The lower part is an enlarged view of the visible light portion. Notice that the diagram shows wavelength measurements in meters. Because meters as a unit of measurement may sometimes become unwieldy and difficult to use, light wavelength is often measured in millimeters or nanometers. Visible light occupies just a small part of the total spectrum and consists of wavelengths from about 400 to 700 nanometers. The 700-nanometer dimension is extremely small. A micron is one-thousandth of a millimeter and a nanometer is one-thousandth of a micron; thus, a nanometer is one-millionth of a millimeter. So you see, you are dealing with a very small measurement when you consider that a millimeter is about 1/25 of an inch. A nanometer is expressed by the symbol "nm."

If you view the entire range of wavelengths in the visible spectrum (from 400 to 700 nanometers), you get the sensation of seeing white light. However, if you see only a small part of the visible spectrum, or a particular wavelength, you get the sensation of seeing color. For example, light with a wavelength of 450 nanometers appears blue, with 550 nanometers it appears green, and with 650 nanometers it appears red. Actually these figures are only approximations. Generally, a range of wavelengths from 400 to 500 nanometers is said to give the sensation of *blue;* 500 to 600 nanometers—green; and 600 to 700 nanometers—red.

If you see various combinations of wavelengths, you get the sensation of seeing different colors. Red, blue, and green are called *primary* colors, and all other colors that we see are combinations of varying amounts of these primary colors. For example, if you see equal portions of the red and green, your eyes see *yellow*. If you see more red than green, the sensation is *orange*. The positioning of these and other colors in the visible spectrum can be seen in figure 1-2.

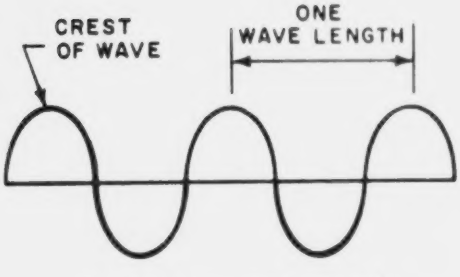


Figure 1-1. Measurement of wavelength.

To the immediate left of the visible spectrum in figure 1-2 are the letters IR. This is the area of *infrared radiation*. Immediately adjoining the visible spectrum on the right, we have an area of *ultraviolet radiation*. These parts of the electromagnetic spectrum can't be properly referred to as light, since they are not visible to the human eye. However, all emulsions are sensitive to ultraviolet, and some emulsions are especially sensitized to infrared.

Exercises (200):

1. Define wavelength.

2. What does the wavelength of visible light determine?

3. Define frequency.

4. How is light defined?

201. Define basic terms that describe the behavior of light.

Behavior of Light. Because light is necessary to make a photographic exposure, you need to know something of the speed of light, of reflection, transmission, absorption, refraction, dispersion, diffraction, color, and polarization. To become a good laboratory specialist, you must understand these terms and their principles. Then, you can effectively use light—the basic tool of the laboratory specialist. You must realize that you use light as an artist uses paints. This is the raw material used to produce the photograph.

Speed. The speed of light—sometimes called the *velocity of light*—in its flight through space is so tremendous that it defies the imagination. The moon is approximately 240,000 miles from the earth, yet light can span that gap in less than 2 seconds. Light travels through space at approximately 186,000 miles per second. As light travels through more dense mediums, such as glass or water (as compared to air), its speed is slowed up somewhat. The speed of light is constant in any medium of given density, but its speed changes as the waves pass from a medium of one density to a medium of a different density, as you can see in figure 1-3.

Reflection. The casting back, or change in direction, of light after striking a surface is called *reflection*. Light striking the surface is called *incident light*. If the surface upon which the light falls is smooth and polished, reflected light bounces off the surface in the same plane and at the same angle as the incident light. The reflections from smooth, highly polished surfaces are said to be *specular*. However, if the surface is rough and irregular, the light is reflected in more than one plane and direction. This reflected light is *diffused*. Study the differences in the two types of reflected light in figure 1-4.

Most objects reflect both specular and diffused, while most of the light reflected by a smooth surface is specular. Diffused reflected light forms the halftones and shadows in photographs. Specular light creates the very bright highlights. Few successful pictures are made with only specular light reflected from the subject.

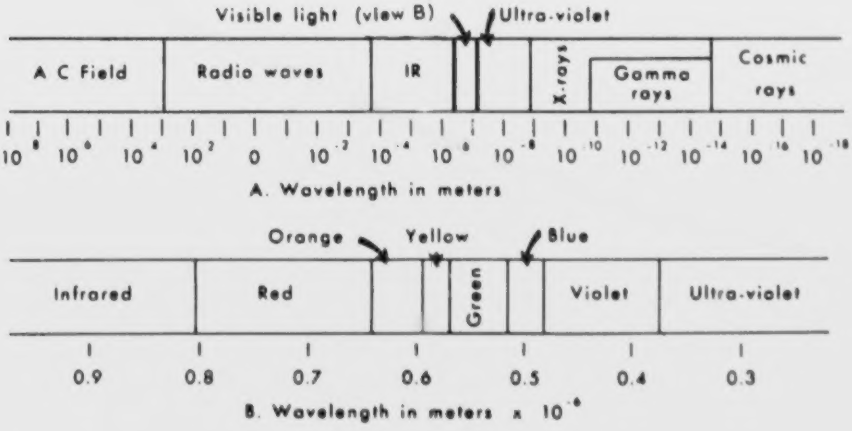


Figure 1-2. The electromagnetic spectrum.

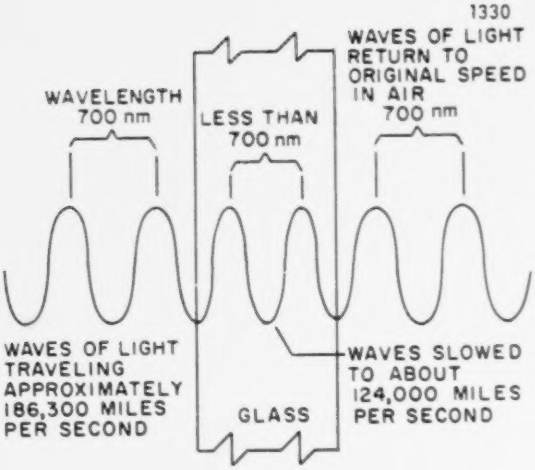


Figure 1–3. Variation in speed and wavelength.

Transmission. The term that describes the passing of light through a medium is transmission. For transmission to take place, the medium must be either transparent or translucent. A *transparent* medium will transmit rays of light through its substance, and any object beyond or behind the medium can be distinctly seen. Figure 1-5 shows that a transparent medium does not give 100 percent transmission. A *translucent* medium transmits rays of light but alters their direction of travel. An object beyond or behind a translucent medium cannot be seen distinctly. Transmitted light passing through a translucent medium is diffused.

If a medium is neither transparent or translucent, it is *opaque*. Light cannot pass through an opaque medium. Observe figure 1-6 and note the differences between transparent, translucent, and opaque mediums.

Absorption. When light is neither transmitted nor reflected by a medium, it is absorbed. Black objects, such as black cloth, black ink, or black suede leather, appear black because they reflect very little of the light that falls upon them. On the other hand, white objects, such as white paper and snow, appear white because they reflect most of the incident light.

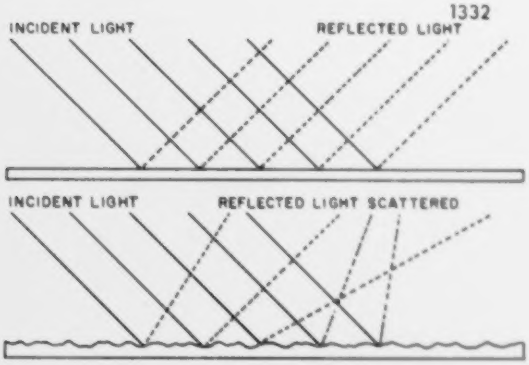


Figure 1–4. Reflection.

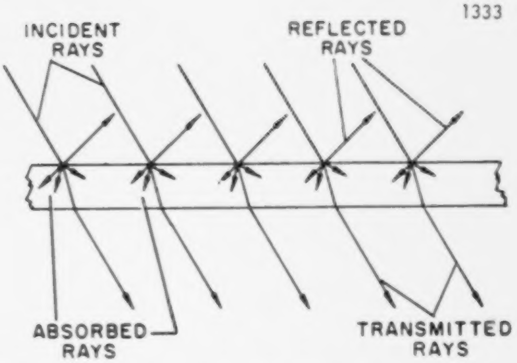


Figure 1–5. Reflection, transmission, absorption of a single medium.

Objects appear as a specific color because of their powers of reflection and absorption. When light falls upon a medium, some absorption and some reflection always take place. No known medium completely absorbs or reflects all of the incident light.

Refraction. The bending of a ray of light is called *refraction*. As light passes from a medium of one density to another medium of a different density, its speed is altered. If the ray of light strikes the new medium perpendicular (90°) to its surface, it passes straight through with no appreciable change in direction. This type of ray is called a normal ray, and the angle the ray makes with the surface of the medium is called the normal angle, or simply, the normal.

If a ray of light enters a new medium at an oblique angle, however, it is bent, or refracted. Figure 1-7 demonstrates the principles of refraction. The law of refraction states that if light enters a *denser* medium at an oblique angle, the light is bent *toward* the normal, or *away from* normal if the new medium is *less dense*.

Refraction makes it possible for a lens to form a sharp image of an object. Light can be bent and directed in any direction and to any degree by (1) controlling the shape of the surfaces of the mediums (flat, convex, or concave), (2) calculating the correct relationship of the surface of the mediums, or (3) choosing mediums with the right density to give the desired effect (flint glass, air, crown glass, etc.)

Dispersion. The variation of the refractive index in relation to the variation of the wavelength of light (increasing as the wavelengths decreases) is known as *dispersion*. As illustrated in figure 1-8, dispersion is also the name given to the separation of white (or complex) light into its constituent colors. It is what causes the prism spectra (the rainbow appearance of light passing through a prism). A ray of white light that strikes a prism at the proper angle is separated into violet, blue, green, yellow, orange, and red light. This is a problem in designing lenses, for if it is not corrected, the various components of light that make up the total image will not focus in the same plane.

Diffraction. When light passes over the edge of an opaque medium it is scattered slightly, or diffracted. Figure 1-9 shows an exaggerated effect of diffraction. You can see diffraction as a shadow with a fuzzy edge when an

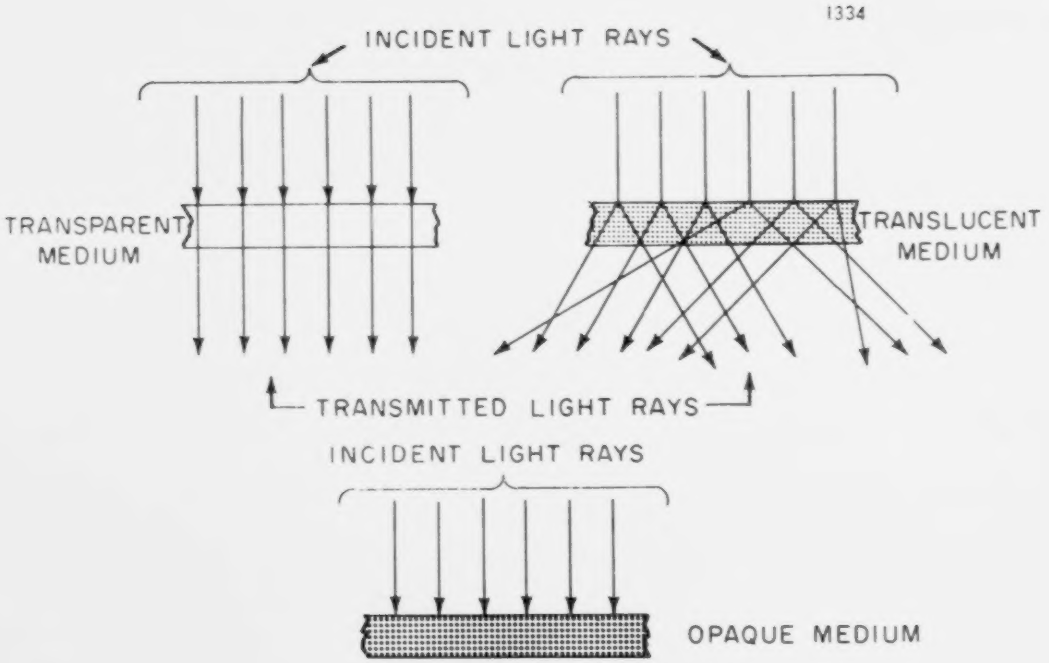

1334
INCIDENT LIGHT RAYS
TRANSPARENT MEDIUM
TRANSLUCENT MEDIUM
TRANSMITTED LIGHT RAYS
INCIDENT LIGHT RAYS
OPAQUE MEDIUM

Figure 1–6. Transparent, translucent, and opaque mediums.

opaque object is placed so that it partially blocks the path of the rays from a point source of light. The outside edge of the shadow is light and indistinct, and it gradually fades into the deep black of the shadow. Thus, you can see that some of the light is scattered into the shadow area. In photography, diffraction takes place as light passes over the opaque edge of the diaphragm in the lens and shutter system.

Color. Objects appear to have color because they reflect and absorb light selectively. For example, an object appears red when light falls upon it because (1) there is some red in the incident light and (2) the object has the ability to reflect the red portion of the visible spectrum and to absorb the other portions. Such an object viewed under pure red light still appears red, but under a pure blue light, it appears black.

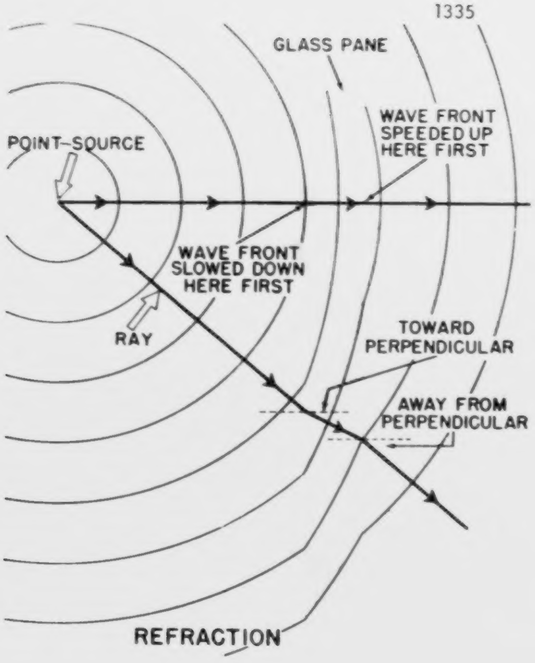

1335
GLASS PANE
WAVE FRONT SPEEDED UP HERE FIRST
POINT-SOURCE
WAVE FRONT SLOWED DOWN HERE FIRST
RAY
TOWARD PERPENDICULAR
AWAY FROM PERPENDICULAR
REFRACTION

Figure 1–7. Refraction.

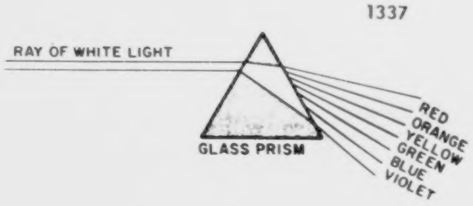

1337
RAY OF WHITE LIGHT
GLASS PRISM
RED
ORANGE
YELLOW
GREEN
BLUE
VIOLET

Figure 1–8. Dispersion.

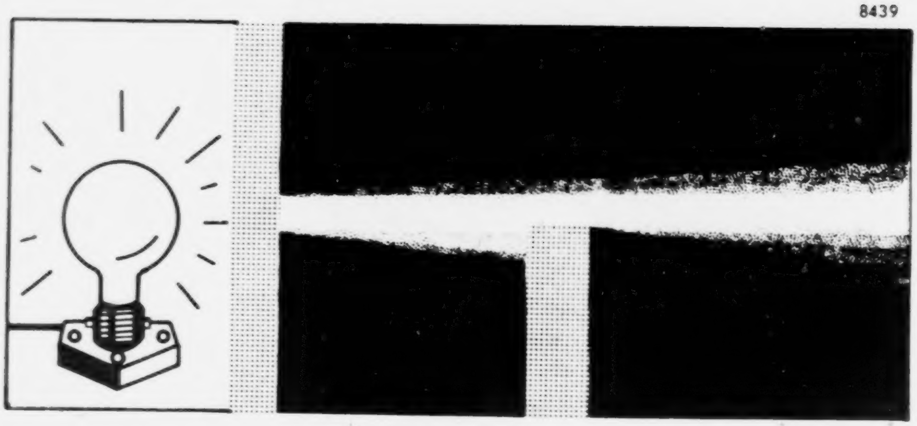


Figure 1–9. Diffraction.

Why does it appear as red or black under the two conditions? Since the light source contains only one color, the reflecting and absorbing characteristics of the object determine what the eye sees. When it reflects the red light, the light is visible. When it absorbs the blue light, the light is not visible. It stands to reason, then, that a red object appears red to the viewer only if the light source contains red *and* the object itself reflects wavelengths in the vicinity of 700 nm (nanometers) and absorbs other wavelengths.

The color of light is an important consideration in photography. Different photographic emulsions are designed to have different sensitivities to the various colors. Therefore, you should consider the quality and color of the light striking the object and the reflective characteristics of the object you are reproducing. How the filters you use affect the image is equally important. The safelight you use in the darkroom is only safe if the material you are handling is not sensitive to the color of the safelight.

Normally, the goal of the laboratory specialist, using black-and-white materials, is to produce a photographic record wherein the brightness values in the print are proportional to the brightness values in the original subject. Not all subject illumination is truly white light, and not all films have equal sensitivity to all colors. It is often necessary to balance the various factors that produce the black-and-white rendition of a colorful subject to give it an appearance of realism in the final print.

Polarization. Another useful characteristic, photographically speaking, is that light can be polarized, or filtered, to vibrate in only one plane. Ordinarily, a ray of light is considered to vibrate in all planes perpendicular to the direction of travel. We can polarize light by using special filters or by making maximum use of natural polarization.

Manmade polarization is done by using a polarizing filter over the light source and/or over the camera lens. Nature polarizes light, but the conditions are very limited. First, light reflected from a *nonmetallic* surface is naturally polarized at an angle of approximately 35°. (There is also some polarizing effect at angles other than this, but the effect is gradually diminished until there is no polarization at 0° or 90°.) Light reflected from a metallic surface is not polarized. Second, light from a clear blue sky at right angles to the sun's rays is also strongly polarized by nature. (This effect diminishes toward 0° and 180°.)

Figure 1-10 illustrates the principles of polarization. The illustration on the left shows natural polarization, and the illustration on the right shows how two polarizing filters act upon light as one filter axis is gradually rotated until it is 90° to the position of the first filter. Light that is made to vibrate in only one plane is said to be *plane polarized*. It is not possible to distinguish plane-polarized light with the unaided eye. This is why its rather frequent occurrence in nature is generally unknown.

Exercises (201):

1. What do we mean by speed of light?

2. What influences the speed of light?

3. Define reflection.

4. What is meant by transmission?

5. State whether each medium is transparent, translucent, or opaque.

   a. Camera ground glass.

   b. Window pane.

   c. Piece of cardboard.

6. What do we call retention of light by a medium (not reflected)?

7. What do we call the bending of light rays?

1-2. Photographic Optics

The optical systems used in recording and reproducing a photographic image must be of top quality to produce the extremely accurate results we want. In addition, such optical systems must also be of the proper design. High resolving power is an absolute necessity. When we have recorded the image on the negative, we must often reproduce this information by optical means to form a final usable print or transparency. Only when the lens quality and lens design are up to the specified standards can we record the image quality that is necessary for truly accurate interpretation.

While there are innumerable designs for optical systems that can create an image, not all optical systems can create an image that's satisfactory for photographic recording. While an optical system may be quite adequate for astronomy, microscopy, or similar uses, this same optical system may be completely inadequate for scientific photographic purposes. You must remember that while the human eye can adapt to many optical deficiencies, the photographic system lacks this adaptability. It records only what it sees, and it records this image exactly as it is.

Application of the optical systems that are available to you is also of extreme importance. The best optical system in the world may not produce usable results if it is improperly applied to the task at hand. Although you have little to do with the design of lenses, you have at your disposal countless optical products to help you get the product you want. To fully understand the various optical devices and their application, you must first be aware of the optical principles that are involved.

202. Cite the principles by which a lens produces an image.

Principles of Lenses. The basic principle of the first and all subsequent lenses is relatively simple. To understand this principle, first consider the image formed with a single pinhole, as shown in figure 1-11. Now consider another pinhole above the first. This pinhole forms a second, but displaced, image. If the two images were made to coincide, the result would be one image twice as bright as either image by itself. Now consider a third pinhole on one side of the first, a fourth on the other side, and a fifth below the first. Each of the five pinholes would project an image that was displaced from the other four images, as shown in figure 1-12. If these five images could be made to coincide, the resultant image would be five times as bright as the image formed by any single pinhole.

Through the principle of refraction, these 5 images could be superimposed. Behind each of the four perimeter pinholes would be a prism whose surfaces were cut and ground to refract each image the right amount to superimpose all five images. The result would be an image five times as brillant as a single pinhole image (fig. 1-13). Extending this principle, you can see that the more pinholes and the more prisms used to form the image, the brighter or more intense the image would become. A system could be made using an infinite number of pinholes and prisms positioned around a single central pinhole, and in effect a lens would be produced. Such a lens, however, would be cumbersome, difficult to manufacture, full of aberrations,

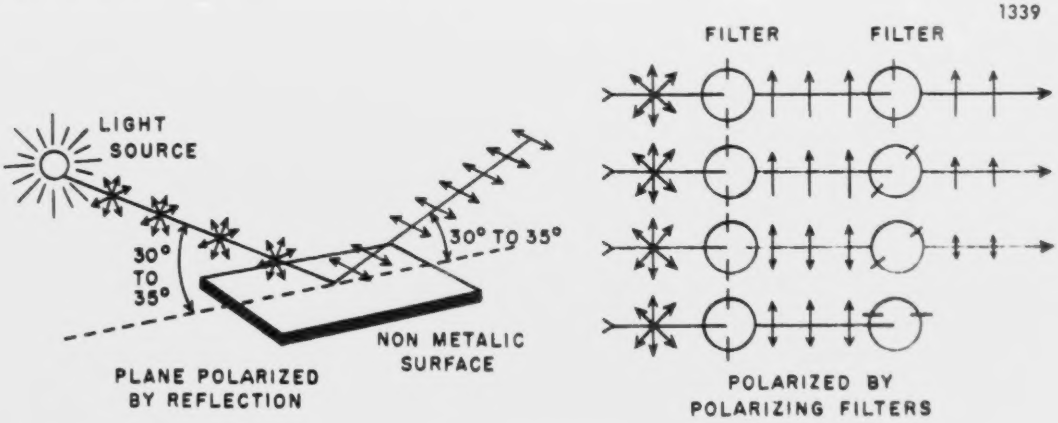


Figure 1-10. Polarization.

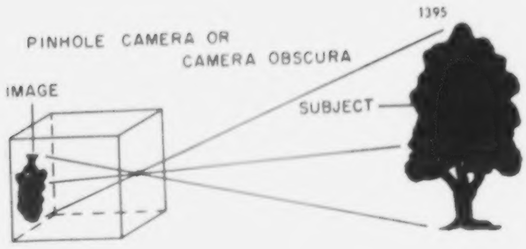

1395
PINHOLE CAMERA OR
CAMERA OBSCURA
IMAGE
SUBJECT

Figure 1–11. Inverted image created by a pinhole camera.

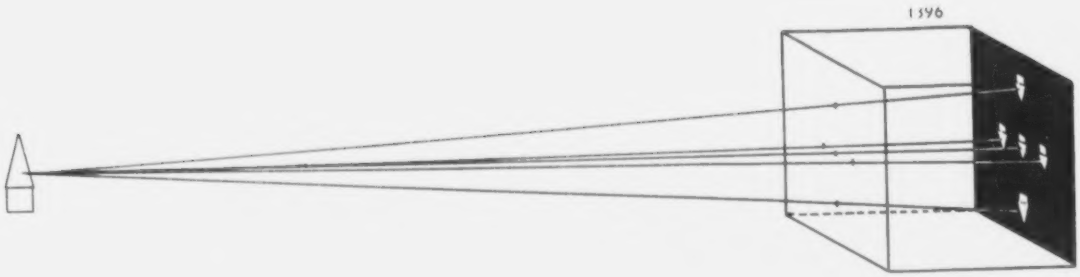


Figure 1–12. Separate images of the same subject.

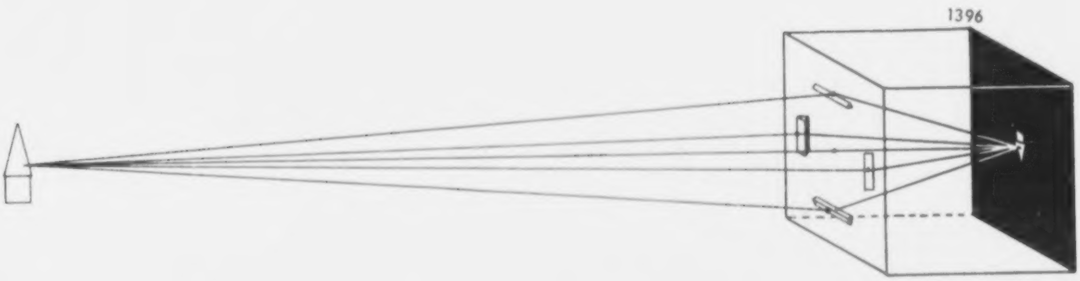


Figure 1–13. Separate images made to coincide.

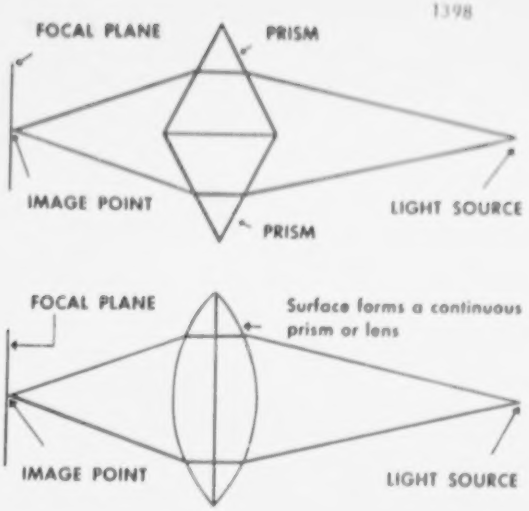


Figure 1–14. The lens principle.

and prohibitive in cost. The problem was solved by making a lens from a single piece of glass. The lens represented an infinite number of pinholes and prisms, or a continuous prism in circular form. This type of circular prism (or lens) eliminated the need for pinholes, because the lens itself formed the image in the same manner as two prisms placed base to base, as shown diagrammatically in figure 1-14.

Further improvement came when the adjustable opening was incorporated into the lens system. When the opening was made larger, more light was allowed to pass through the lens; when it was made smaller, less light was allowed to pass. The use of a lens not only increased the brightness of the image, but it also improved the image sharpness and enabled the user to control the image size from specific distances. Brightness of the image was improved by controlling lens diameter; image sharpness was improved by minimizing diffraction; and image size was controlled by the focal length (the shape of the lens and the materials used).

Exercises (202):

1. What principle is used to bend light rays so that they form a single image?

2. What determines the brightness of the image formed at the film plane?

203. Identify the various types of lens shapes.

Present-Day Lenses. Figure 1-15 shows how a wave front is affected when it strikes the curved surfaces of a positive lens. (A positive lens is thicker in the middle than it is at the edges.) The wave front slows as it enters the glass because glass is more dense than air. The front slows first at the center of the lens and, since the center is thicker than the edges, the wave front leaves the edges first. The outer edge of the front speeds up before the part that's still traveling through the denser glass. The result is a reversal in the wave front, which converges to form a point behind the lens, termed the "focal point." This focal point represents the original point source, and it continues onward to create a second wave front behind the focal point.

The way the inverted image is constructed is illustrated in figure 1-16, which shows just two of the millions of points that reflect light. In actual practice, all of the focal points combine to form the total image. Notice that the image is inverted and is formed behind the lens at a plane termed the "focal plane."

The lens in figure 1-16 is a simple biconvex positive lens and is nothing more than a cross-sectional view of an ordinary magnifying lens. Now look at figure 1-17 and notice the variations in shape of positive and negative lenses. Remember that there is a basic system of nomenclature: (1) The prefix "bi" indicates that the descriptive term applies to both surfaces; i.e., biconvex (both surfaces are convex). (2) The prefix "plano" indicates a flat surface; i.e., plano-convex (one surface flat, the other convex). (3) Finally, the first word in the two-word combination indicates the predominant characteristic; i.e., concavo-convex (a lens with one concave surface and one convex surface—the concave surface having greater

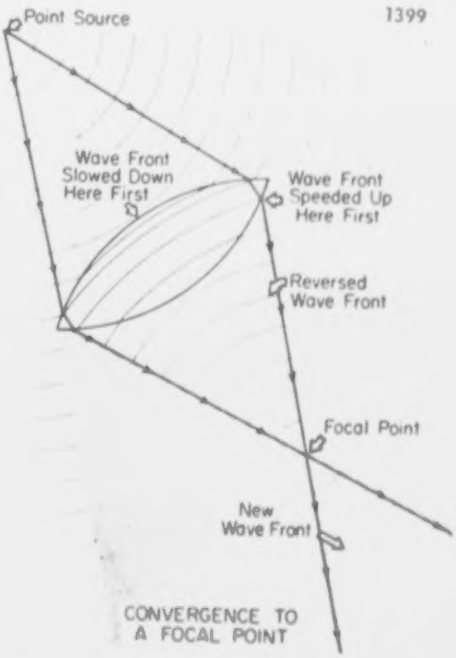

Point Source
1399
Wave Front Slowed Down Here First
Wave Front Speeded Up Here First
Reversed Wave Front
Focal Point
New Wave Front
CONVERGENCE TO A FOCAL POINT

Figure 1–15. Effects of positive lens on a wave front.

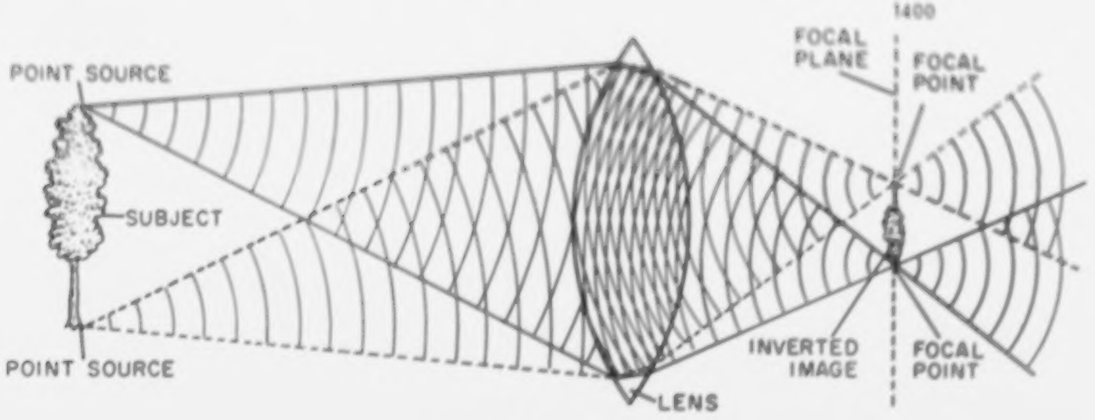

1400
FOCAL PLANE
FOCAL POINT
POINT SOURCE
SUBJECT
POINT SOURCE
INVERTED IMAGE
FOCAL POINT
LENS

Figure 1-16. Image formation.

curvature than the convex surface). A convexo-convex lens would be a negative lens.

Since we have already found that a positive lens forms an inverted image, let us now consider what happens to a wave front when it strikes a negative lens (fig. 1-18). Since the center of the lens is thinner than the edges, the wave front is actually exaggerated, and the rays tend to diverge behind the lens. The negative lens does not form an image the same way the positive lens does, but instead forms a virtual, erect, in-front-of-the-lens image that is smaller than the object. Carefully compare figures 1-15 and 1-18 so that you fully understand what happens to light as it passes through the two basic types of lenses.

A high-quality photographic lens is usually a combination of two or more of the simple lenses, mounted together in a single lens barrel or sometimes in two separate lens sections separated by a shutter. We must combine two or more individual lenses to correct faults (aberrations) that are found in the simple lens. Designing such a high-quality photographic lens is definitely an engineering feat. To develop a lens that can perform efficiently within very critical specifications may take both considerable time and a great deal of money. We'll have more details on the quality of lenses and their aberrations later in this chapter.

When a negative lens is used in combination with a positive lens to form a photographic lens, the positive lens

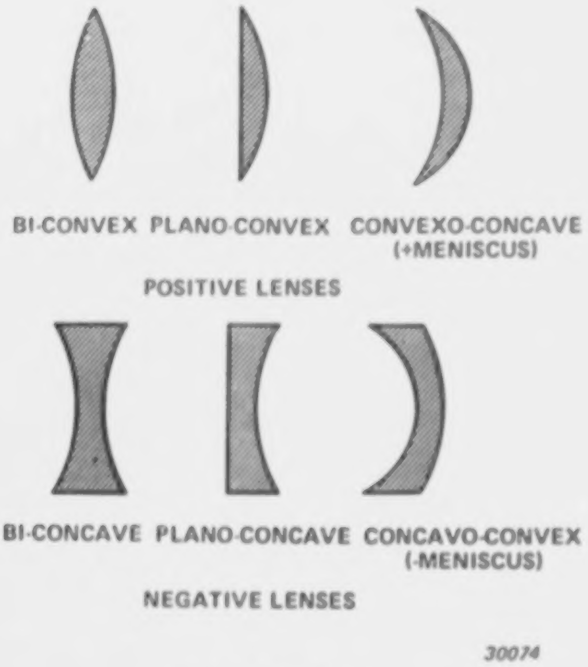

BI-CONVEX
PLANO-CONVEX
CONVEXO-CONCAVE (+MENISCUS)
POSITIVE LENSES
BI-CONCAVE
PLANO-CONCAVE
CONCAVO-CONVEX (-MENISCUS)
NEGATIVE LENSES
30074

Figure 1-17. Simple lenses.

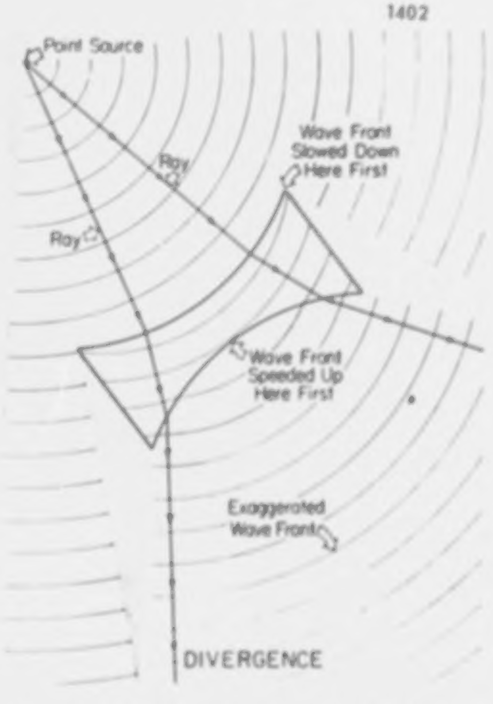

1402
Point Source
Ray
Ray
Wave Front Slowed Down Here First
Wave Front Speeded Up Here First
Exaggerated Wave Front
DIVERGENCE

Figure 1-18. Effects of a negative lens on a wave front.

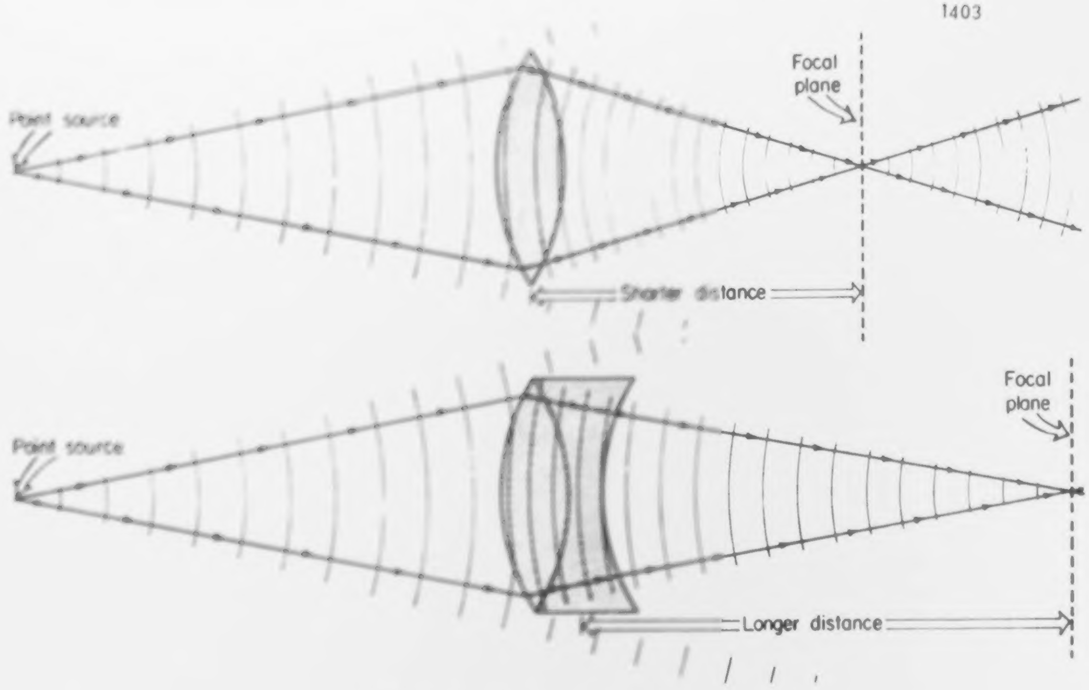


Figure 1-19. Simple and combination lenses.

has to be stronger than the negative lens. The total combination must remain as a positive lens. A negative lens used in combination with a positive lens makes the image fall farther behind the lens than does a positive lens used by itself.

Figure 1-19 shows how a simple positive lens forms the focal points on a plane relatively close to the lens. This figure also shows how adding a negative lens to the same positive lens causes the image to fall on a plane much further from the lens. The stronger (more diverging) the negative lens is with respect to a given positive lens, the further from the lens the image will be. You should realize that if the strength or refraction of both lenses (positive and negative) were equal and opposite, no image would be formed behind the lens, and only a virtual image would be formed in front of the lens.

Lens quality depends on the design of the lens, the accuracy of the lens grinding to design specifications, and the ingredients and techniques used in lens manufacture and assembly. Assuming that the grinding and assembly of the lens are in accordance with specifications, the lens quality then is limited to design characteristics and composition of the components. In addition to design changes, continuous research is being done to make better glasses and combinations of glasses that can be used in conjunction with the improved designs. Each year new lenses are marketed, and the improvement in optics is continuous.

Exercises (203):

Name the lens shapes on figure 1-20 and state whether each is positive or negative.

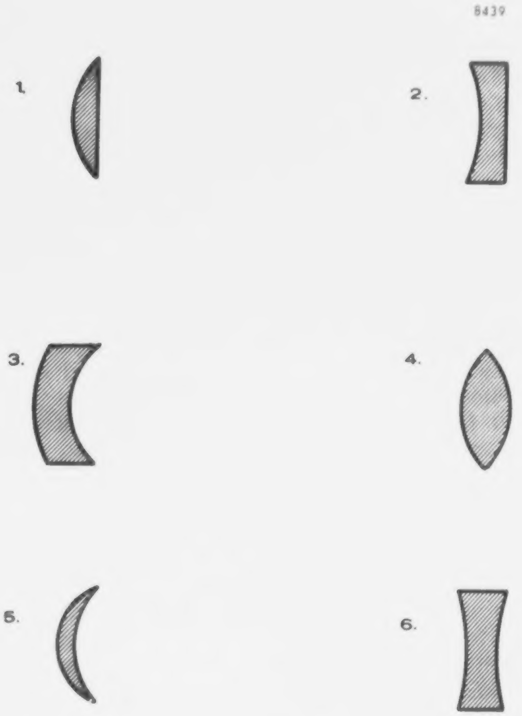


Figure 1–20. Lens shapes (objective 203, exercise 1–6).

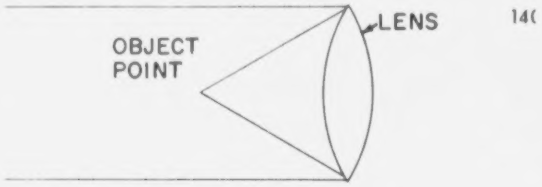
204. For given circumstances, state whether you should use long, short, or normal length focal lenses.

Characteristics of Lenses. There are many items we must include when we consider the characteristics of a lens. For you to perform well in photography, it is essential that you recognize the effect of these lens characteristics. Realize that it is the use and the recognition of these various lens features and qualities that make the difference between good and poor photography. You must learn to recognize the photographic effect of these principles and know how they can be applied to improve your work. Finally you must learn how some of the lens characteristics may limit your photographic operation capability.

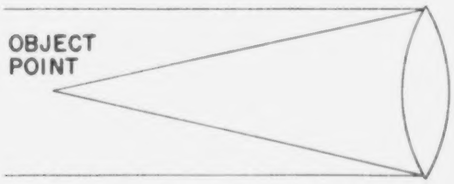
Focal length. The term "focal length" is defined as the distance between the optical center of the lens and the image produced by the lens when the lens is focused on infinity. To understand this definition, you must understand the terms "optical center" and "infinity."

The optical center of a lens is a point, usually (but not always) within a lens, at which the rays of light from two different sources entering the lens are assumed to cross. The term "infinity" is not easily described. When light is reflected from a point on an object through a lens, the closer the point to the lens, the greater is the angle of the spread of the light rays from the object to the lens. As the point gets farther away from the lens (fig. 1-21), the angle of spread becomes less and less. This continues until a distance is reached at which the rays from a single point striking top and bottom of the lens, for all practical purposes, can be considered parallel. This distance is known by the term "infinity."

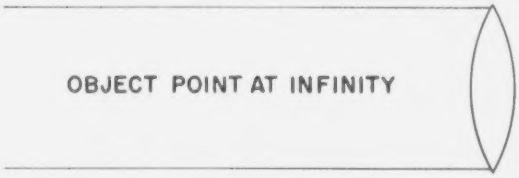
Infinity is expressed by the symbol "∞" Infinity is a computable distance, far from the lens, which can be determined when the individual characteristics of the lens are known. The wave front from a point at the infinitely far away distance appears straight in relation to the diameter of



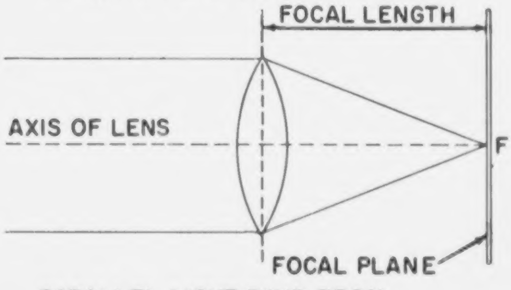
RAYS FROM A NEAR POINT TO A LENS SPREAD CONSIDERABLY



RAYS FROM A FAR POINT SPREAD A LITTLE



PARALLEL RAYS FROM A POINT AT INFINITY (INDEFINITE DISTANCE) DO NOT SPREAD SIGNIFICANTLY



PARALLEL LIGHT RAYS FROM INFINITE DISTANCE DETERMINE FOCAL LENGTH

Figure 1–21. Effect of lens-to-subject distance on light rays.

the lens. Therefore, the rays from such distance point sources are said to be parallel when entering the lens. *For all practical purposes*, we can consider light rays from a very distant object, or an object at 100 or more yards, to be parallel, but this is *only* for practical purposes. When we're using very long focal length lenses or telephoto lenses, 100 yards may be much less than infinity.

The way the light rays are refracted by the lens determines the focal length. This refraction, in turn, depends on the nature of the glass used in the elements, the curvature of the element surfaces, and the separation of the elements. The first two factors are fixed quantities once the lens is manufactured, but the third factor can be changed individually in certain lenses. In some lenses, parts of the lens can be used by themselves. In others, the distance separating the lens elements can be altered. By either method, the focal length of thesese lens can be altered. If one of the two conditions can't be met, the focal length is fixed and constant.

Photographic lenses are measured according to their focal length. The focal length is normally imprinted somewhere on the lens mounting (usually the front surface of the lens barrel). This focal length information is sometimes given in inches, sometimes in millimeters, and occasionally in both systems.

A knowledge of focal length as related to photographic lenses is important because the focal length dictates the size of the image produced by a given lens at a given lens-to-subject distance. Focal length also determines the minimum distance between the lens and the focal plane of the camera. The normal focal length lens for a camera is approximately equal to the diagonal dimension of the film used to record the image. Since the diagonal dimension of an 8- by 10-inch film is 12.8 inches, a lens in the vicinity of 12 or 13 inches is a normal lens for such film. By the same token, a 4- by 5-inch film has a diagonal dimension of 6.4 inches and a normal lens for it would be approximately 6.4 inches. Unless a lens is designed especially for wide-angle photography, a lens shorter than the normal focal length limits the use of both the rising-and-falling front and the lateral shift. Under such limitations, you must take care, or the film may be outside the total image projected by the lens. You can use lenses with longer-than-normal focal length on a camera if you can increase the distance from the lens to the film enough to accommodate the increase in focal length.

Focal length and image size. A lens with a long focal length produces a larger image than one with a short focal length at the same lens-to-subject distance. In effect, the longer focal length lens brings the subject closer to the camera without changing the camera-to-subject distance. For example, a man 6 feet tall stands 25 feet from three cameras, one with a 6-inch lens, one with a 12-inch lens, and one with a 24-inch lens. The 6-inch lens produces a 1½-inch image of the man on the focal plane. The 12-inch lens produces an image that is 3 inches high. Finally, the 24-inch lens produces a 6-inch image on the focal plane. From this example, it is obvious that the longer the focal length of the lens, the larger the image size of a given object from a given lens-to-subject distance.

Focal length and subject coverage. Focal length and subject coverage go hand in hand—just as do focal length and image size. But, whereas image size increases with increased focal length, coverage decreases with increased focal length. We can consider coverage as the amount of subject matter included in a given format size from a given lens-to-subject distance. With three cameras of three different focal lengths set up the same distance from the same subject, the camera with the shortest focal length includes the most subject area—the camera with the longest focal length includes the least. Both image size and coverage in relation to focal length can be seen in figure 1-22, which shows the same subject taken from the same viewpoint with three different focal length lenses. You must understand the effect of focal length on image size and coverage to use lenses to their greatest advantage. Be sure you understand the principles set forth pictorially in figure 1-22.

Exercises (204):

1. Should you use a long, normal or short focal length lens in these work situations?

   a. You want maximum coverage of a scene.

   b. You want maximum size of a small object.

   c. A scene in which you want minimum distortion.

   d. Maximum coverage of the interior of a room.

205. Use the lens speed equation to compare the speeds of different lenses.

Lens Speed. One major characteristic of a lens is its speed. The term "lens speed" refers to the largest possible aperture of a lens—the maximum amount of light that a lens allows to pass to the focal plane and form the image. Lens speed, usually indicated by a numerical value termed an "f/number," depends on two factors: the maximum aperture of the lens (D) and the focal length of the lens (FL). The relationship between focal length and diameter in determining lens speed is expressed as

$$\text{Lens speed} = \frac{\text{FL}}{\text{maximum D}}$$

You can easily see from figure 1-23 that, focal length remaining constant, a lens with a larger opening allows more light to reach the focal plane than does a lens with a smaller opening. The lens with the larger opening can therefore produce a brighter image than the one with the

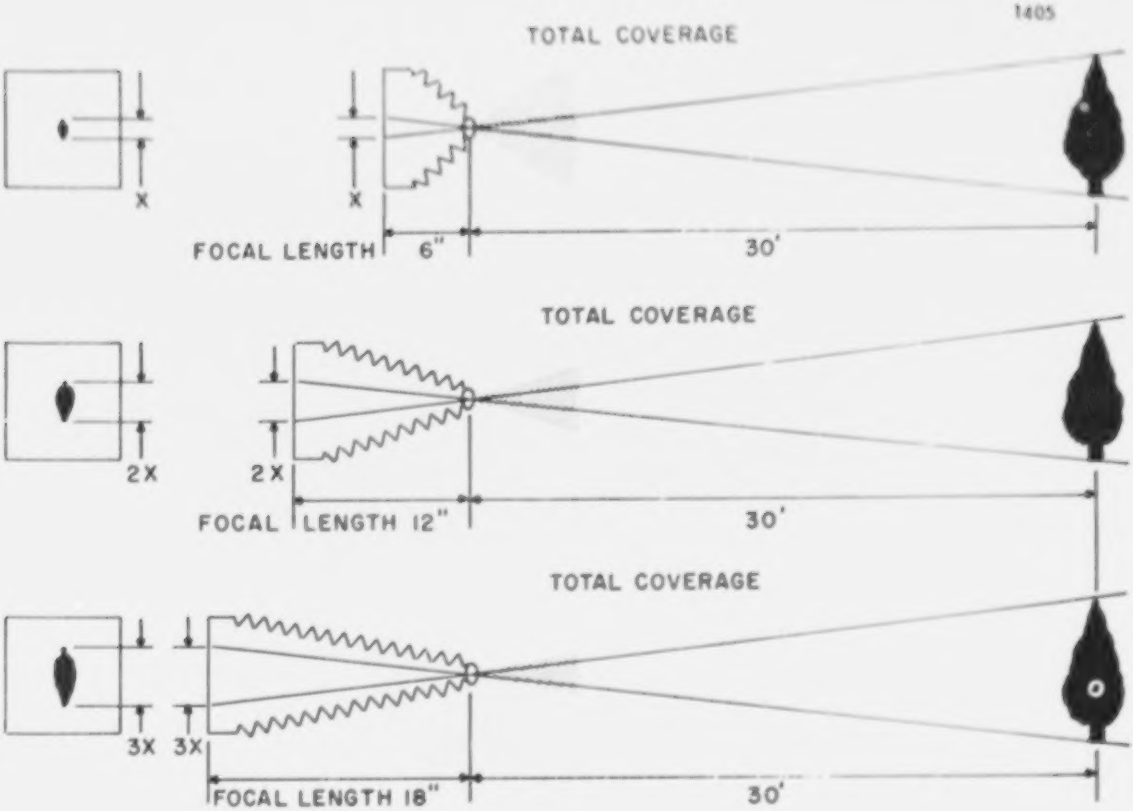

1405
TOTAL COVERAGE
X
X
FOCAL LENGTH
6"
30'
TOTAL COVERAGE
2X
2X
FOCAL LENGTH 12"
30'
TOTAL COVERAGE
3X
3X
FOCAL LENGTH 18"
30'

Figure 1-22. Image size and coverage as compared to focal length.

smaller opening and is termed "faster." Conversely, the lens with the smaller opening is termed "slower."

Now observe figure 1-24 and notice that if the aperture stays constant, the focal length affects the image brightness. Since the light has less distance to travel from the lens to the focal plane in the short focal length lens, the image is brighter and the lens is considered faster. Conversely, the lens with the same aperture, but a longer focal length, is considered slower. The terms "fast" and "slow" are only relative, and there is no definite dividing point between the two. The effect of focal length on image brightness can be compared to shining a flashlight on a white card. The farther the distance from the flashlight to the card, the dimmer the light becomes, or the less illumination the card receives.

To summarize, for a given focal length, the speed of a lens varies *directly* with the size of the aperture—the larger the aperture, the faster the lens and the brighter the image. For a given aperture, speed varies *inversely* as the focal length of the lens varies—the longer the focal length of the lens, the slower the lens and the dimmer the image.

To fully realize the significance of variations in focal length on lens speed, you should understand the *inverse-square law,* which states that the intensity of light varies inversely with the square of the distance of the light from its source:

$$\text{Intensity} = \frac{1}{\text{distance}^2}$$

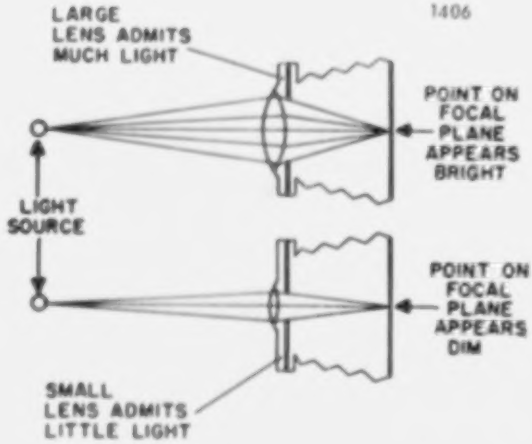

1406
LARGE LENS ADMITS MUCH LIGHT
POINT ON FOCAL PLANE APPEARS BRIGHT
LIGHT SOURCE
POINT ON FOCAL PLANE APPEARS DIM
SMALL LENS ADMITS LITTLE LIGHT

Figure 1-23. Effects of lens aperture on image brightness.

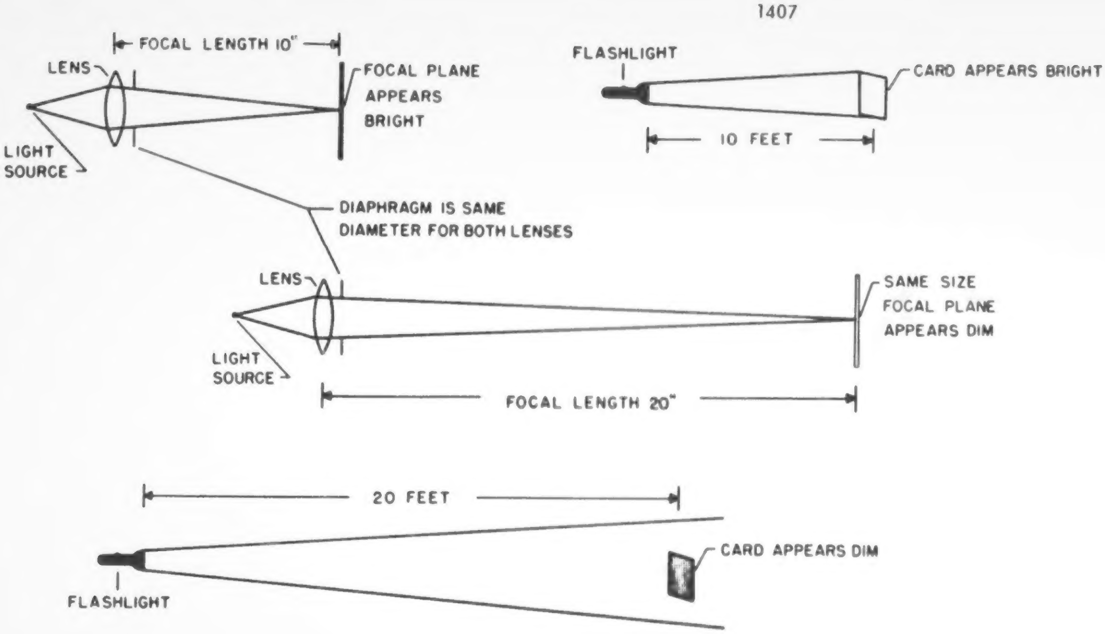

1407
FOCAL LENGTH 10"
LENS
FOCAL PLANE APPEARS BRIGHT
LIGHT SOURCE
FLASHLIGHT
CARD APPEARS BRIGHT
10 FEET
DIAPHRAGM IS SAME DIAMETER FOR BOTH LENSES
LENS
SAME SIZE FOCAL PLANE APPEARS DIM
LIGHT SOURCE
FOCAL LENGTH 20"
20 FEET
CARD APPEARS DIM
FLASHLIGHT

Figure 1–24. Effects of focal length on image brightness.

As an example of how this law works, observe figure 1-25. If you place a card 1 foot from a light source, the light striking the card is of a certain intensity. If the card is moved 2 feet away, the intensity decreases with the square of the distance (2^2 or 4 times) and is one-fourth as bright. If the card is moved 3 feet away, the decrease is 3^2, or the light is one-ninth as intense. If the card is placed 4 feet away, the intensity drops to 1/16 of the original intensity. *In photographic work, the lens acts as a light source for the film.*

Since speed of a lens is the ratio of maximum aperture to focal length, many combinations can provide a specific lens speed. For instance, a lens with a maximum diameter of 1 inch and a focal length of 2 inches would have a speed of f/2. But a lens 6 inches in diameter with a focal length of 12 inches would also have a speed of f/2, as would a lens having a diameter of 100 inches and a focal length of 200 inches.

Observe figure 1-26 and make sure you fully understand the principle. Since lens B has four times the area of lens A, it projects four times as much light to the focal plane, but this light must travel twice as far to reach the focal plane. According to the inverse-square law, the increase in distance traveled decreases the intensity to one-fourth; therefore, the light reaching the focal plane of camera B is of the same intensity as the light reaching the focal plane of camera A.

Exercises (205):

1. Use the lens speed equation to determine which lens would be rated fastest.

	Lens A		Lens B	
	FL	D	FL	D
____ a.	6 inches	1 inch	9 inches	1.4 inches
____ b.	18 inches	2 inches	14 inches	6 inches
____ c.	3 inches	2 inches	5 inches	3 inches
____ d.	9 inches	3 inches	8 inches	2.7 inches
____ e.	12 inches	3 inches	10 inches	2.5 inches

206. State the meaning of resolving power, definition, and acutance.

Resolving Power. The term "resolving power" refers to the ability of a photographic lens or material to form an image of, or record, fine detail distinguishably. The normal method of measuring this quality is to photograph a suitable test pattern at a greatly reduced scale and then examine the developed image under enough magnification to determine the smallest detail that is resolved. Resolving power should

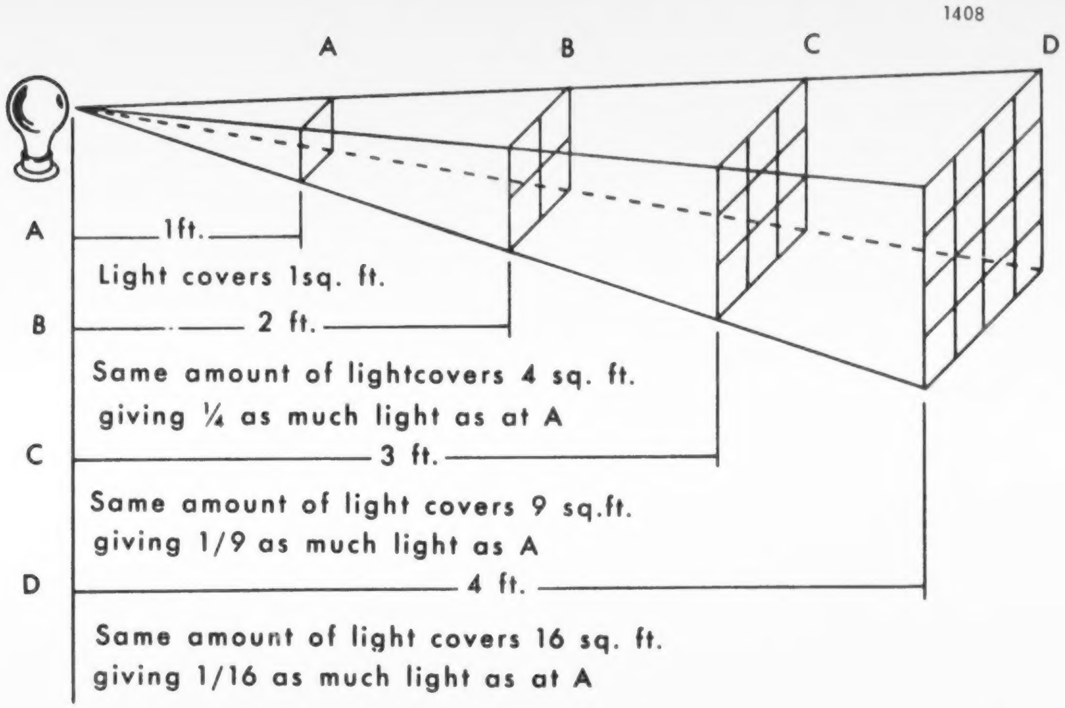

1408
A
B
C
D
A
1ft.
Light covers 1sq. ft.
B
2 ft.
Same amount of lightcovers 4 sq. ft.
giving ¼ as much light as at A
C
3 ft.
Same amount of light covers 9 sq.ft.
giving 1/9 as much light as A
D
4 ft.
Same amount of light covers 16 sq. ft.
giving 1/16 as much light as at A

Figure 1–25. The inverse-square law.

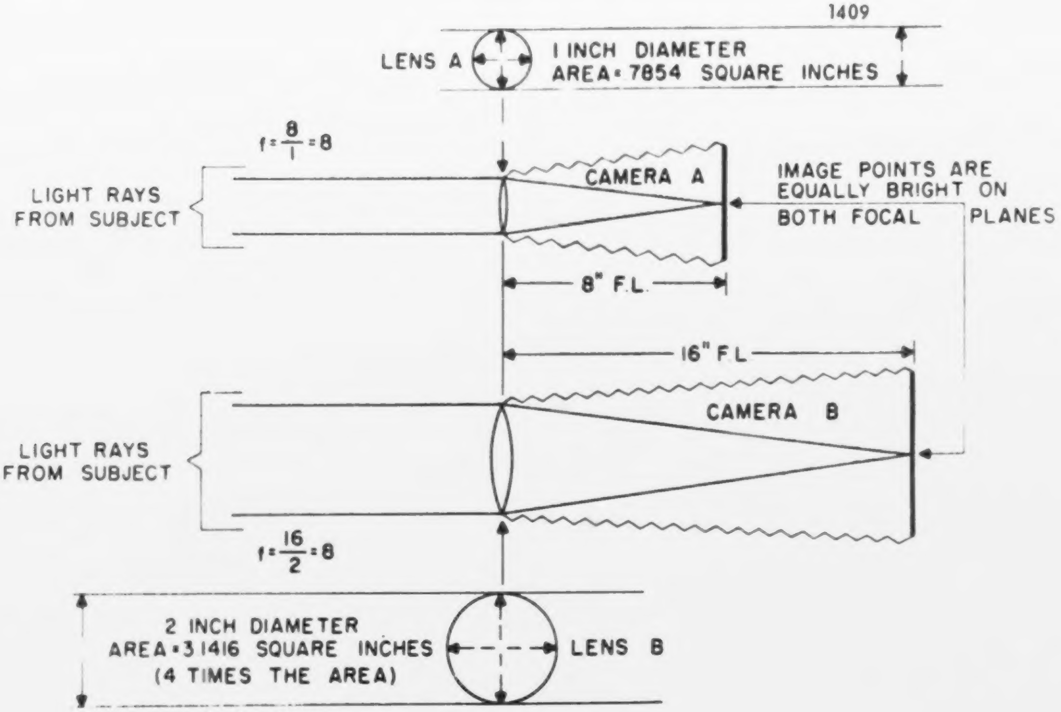

1409
LENS A
1 INCH DIAMETER
AREA = 7854 SQUARE INCHES
f = 8/1 = 8
LIGHT RAYS FROM SUBJECT
CAMERA A
IMAGE POINTS ARE EQUALLY BRIGHT ON BOTH FOCAL PLANES
8" F.L.
16" F.L.
CAMERA B
LIGHT RAYS FROM SUBJECT
f = 16/2 = 8
2 INCH DIAMETER
AREA = 3.1416 SQUARE INCHES
(4 TIMES THE AREA)
LENS B

Figure 1–26. How two lenses can have the same f/value.

usually be considered with respect to a lens-film combination. The resolving power of a lens by itself, or a film by itself, indicates little, since the final photographic product is necessarily a result of the combination.

The resolving power of a lens-film combination varies with such things as exposure, development, and subject contrast. Because of the effect of variables on the resolving power, the measurement is usually determined under strictly controlled conditions. Many different test patterns have been used by the photographic industry to determine resolving power, but the Air Force closely regulates its measurement in determining lens quality. Military Standard MIL–STD–150 prescribes the test pattern and other influencing factors that must be maintained as standards for accurate measurements of Air Force equipment. At the present time, the ratings of resolving power are given in terms of the "lines per millimeter" that can be distinguished.

The resolving power (in lines per millimeter from a given focus position at the various angles out to the corners of the sensitized material) is weighed by the percentage of the area of the zone in which the angles occur in the total area of the picture. This system of rating resolving power is known by the term "area weighted average resolution" and abbreviated by the letters "AWAR." The thing that is most important photographically is not only the maximum resolving power, but whether the resolving power is ample over the entire format and over the range of densities or tones that are to be recorded in making the negative.

Definition. Photographic definition refers to the quality aspect of a photograph that is associated with the clarity of detail. Since photographic definition is an impression made on the mind of an observer viewing a photograph, the concept becomes subjective and depends on the viewer. In common terms, definition is a composite effect of at least four subjective factors: resolving power, sharpness, graininess, and tone reproduction.

In general, emulsion or lenses of high resolving power make better pictures than emulsions or lenses of low resolving power, but evidence has been accumulated to indicate that resolving power and definition do not always correlate. In some instances, resolving power by itself may even be misleading when you are judging image quality. You must realize that resolving power is a measure of only one of the factors affecting definition (i.e., the ability of the system to reproduce closely spaced detail). If a system had enough resolving power to reproduce all of the detail that can be distinguished by the human eye for a given set of viewing conditions, quality of definition in the photographic reproduction would still depend on the sharpness of the image. That is, under such conditions, the quality of definition depends on sharpness, graininess, and tone reproduction.

Within recent years, it has become increasingly apparent that using resolving power as the sole criterion of quality is deceptive. In the first place, resolving power depends on many variable factors. In the second place, the criterion of resolution is uncertain. Moreover, ordinary negative materials can resolve lines that are about 10 times finer than can be resolved visually in a contact print at the ordinary reading distance. Normally, the observer of a photograph is not as interested in the resolution of barely visible details as in seeing the larger details clearly.

Acutance. This brings us to a third term—"acutance." Acutance is a measure of the edge sharpness of the individual grains that make up a photographic image. Acutance is one of the large determining factors in definition when resolving power in a photograph exceeds about twice that of the eye (for the conditions of observation). Figure 1-27 illustrates that when a test pattern is reproduced photographically, the acutance can be high with low resolving power or can be low with high resolving power. Such conditions as this would become apparent only under conditions of very high magnifications.

While both resolving power and acutance are important to overall definition, a photograph can have very fine resolving power and yet not look good because acutance is poor. On the other hand, a photograph can have high acutance and look good even though, under powerful magnification, it contains very little fine detail because the resolving power is poor.

Exercises (206):

1. To what does the term "resolving power" refer?

2. Why is it unrealistic to speak of the resolving power of a lens?

3. What factors determine photographic definition?

4. Which demands the best photographic definition—low-or high-attitude aerial photographs?

5. What is another name for edge sharpness?

207. Given a list of image defects, state what lens aberration produced each defect.

Aberrations and Deficiencies. In most discussion of optics, it is assumed that the lens produces a perfect image. This is not true. There are at least six general types of lens imperfections or aberrations. Any single-element positive lens can project an image. However, because single-element lenses suffer from various aberrations, the images they project are not always faithful reproductions of the original subject. By combining lenses of different shapes and refractive indices, aberrations can be reduced to tolerable limits. Such is the case in the well-corrected lenses used in the cameras of today.

14 10

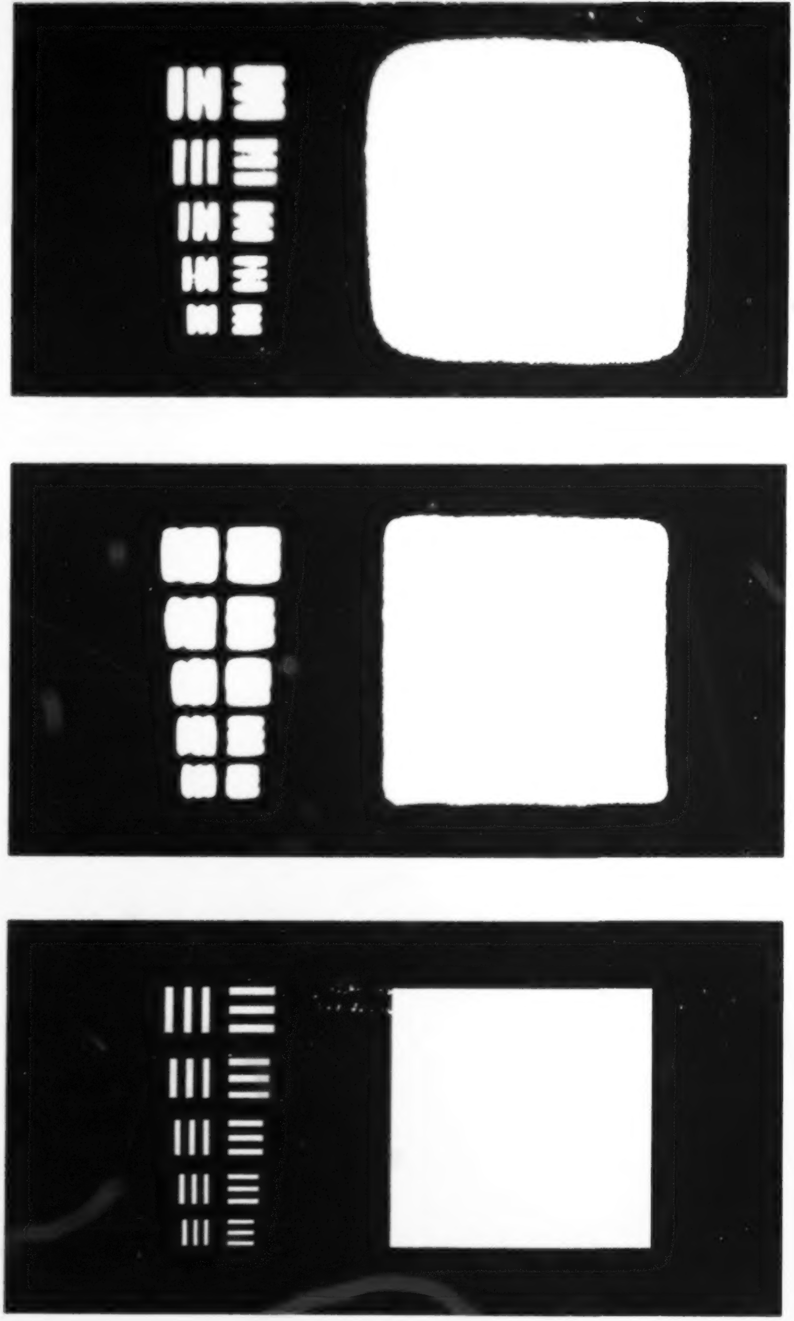


Figure 1–27. Acutance and resolving power.

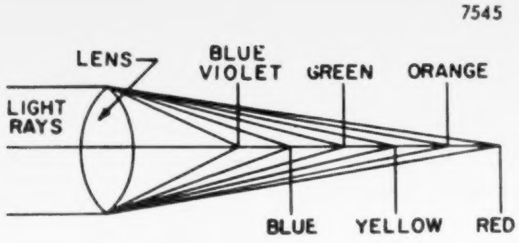


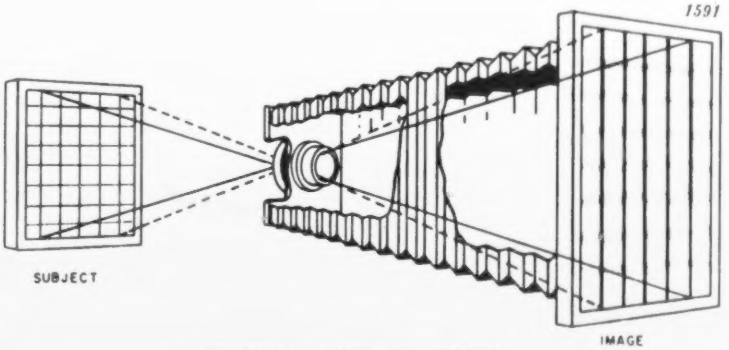
Figure 1-28. Chromatic aberration.

There is little you can do about lens aberrations, but you must recognize that they do exist to some extent in even the very best of lenses and that their effects may limit the quality of the photograph produced by the lens. Finally, you must know that to produce the desired quality in a photograph you may have to use special lenses that have been designed for specific purposes. No lens is perfect, and none projects a perfect image—you must recognize this fact.

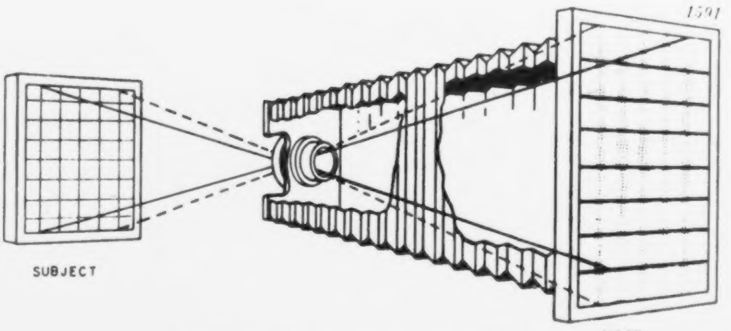
Chromatic aberration. Chromatic aberration refers to the inability of a lens to bring all the colors of the visible spectrum to the same plane of focus. In figure 1-28 you can see how a lens that is not corrected for chromatic aberration focuses the various colors of the spectrum at different planes even though they originate from the same source. This aberration forms color fringes around the image points, representing points of a subject that is reflecting complex light. All colors will not be of equal sharpness at the same plane, and unless a single color is being recorded, the lens with chromatic aberration cannot function satisfactorily.

A lens that has been corrected enough to bring the yellow and blue-violet rays to focus on a common plane is an "apochromat," or a lens corrected for three colors. Generally, apochromatic lenses are used by photoengravers and copy personnel working with color separation and similar work.

Astigmatism. The lens aberration characterized by inability to bring horizontal and vertical lines together at a common plane of focus is known as astigmatism. It is



VERTICAL LINES IN FOCUS



HORIZONTAL LINES IN FOCUS

Figure 1-29. Astigmatism.

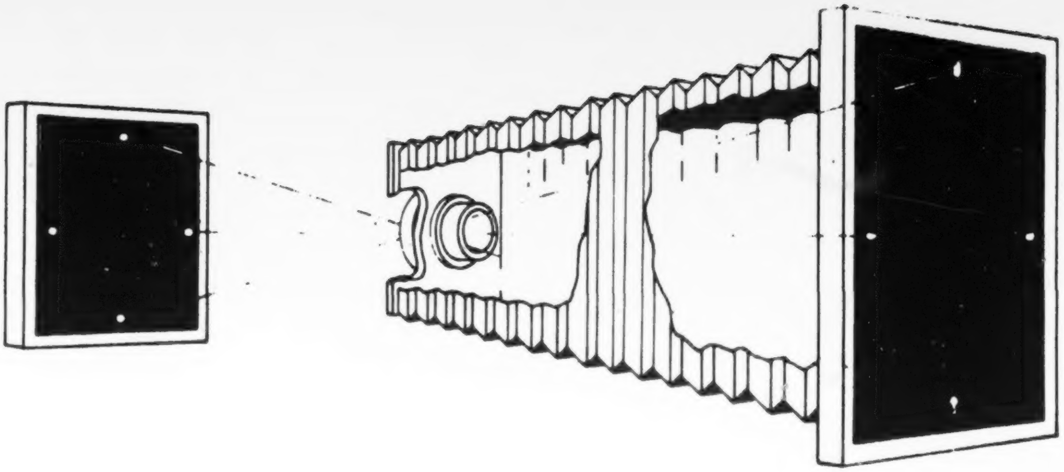


Figure 1-30. Coma.

especially noticeable at the outer edges of the image (fig. 1-29). When the vertical lines are brought into focus, the horizontal lines are out of focus. Conversely, when the horizontal lines are brought into focus, the vertical lines are out of focus. When a lens has been corrected for astigmatism, it is "anastigmat."

Coma. The aberration caused by the inability of a lens to bring oblique rays to a common point with equal magnification and brightness is termed "coma." Light rays passing through a single lens at an oblique angle come to focus in the same plane, but fall at different points, rather than being superimposed. The image formed by the ray that strikes nearest the center of the lens produces the smallest and brightest point. The rays striking the lens toward the edges produce images that are increasingly larger and dimmer. The total effect is an image of a point that is smallest at its brightest end and grows larger toward its dimmest end (fig. 1-30). Because the image of a point tends to resemble that of a comet, the aberration was named coma. The term "aplanat" refers to doublet lenses that are free from coma and spherical aberration (which we will consider next).

Spherical aberration. Spherical aberration is the defect caused by rays that pass through the margin of the lens and come to focus either nearer to or farther from the lens than rays passing through the center of the lens (fig. 1-31). Most photographic lenses are corrected for this aberration, but a certain amount of spherical aberration is purposely left in soft-focus lenses to give softness to the image. Such lenses are designed primarily for portraiture. Spherical aberration is especially noticeable in short-focus, single-element lenses, where the curvature of the lens is quite pronounced.

Curvature of field. The aberration caused by the inability of a lens to form images of flat objects on one flat plane is called curvature of field. A lens with curvature of field forms an image that is in focus only on a spherical surface (fig. 1-32). Since the average camera has a flat focal plane, it is not possible to get the entire image in focus with a single position of the focal plane. Curvature of field differs from spherical aberration in that its image softness results from a difference in focus between *axial* and *oblique* rays, whereas image softness in spherical aberration is caused by a difference in focus between *marginal* and axial rays.

Curvilinear distortion. An aberration that results in the incorrect rendering, in the image, of straight lines in the subject is called curvilinear distortion (fig. 1-33). If a rectangular test object is focused on the ground glass back of a view camera and the lens is subject to curvilinear distortion, results will be as shown. If the diaphragm is in front of the lens, straight lines tend to be bent outward to give a "barrel" form of distortion. When the diaphragm is behind the lens, straight lines in the subject are curved inward in the image. This causes a "pincushion" type of distortion. This aberration can be especially bad when the lens is being used for copy purposes.

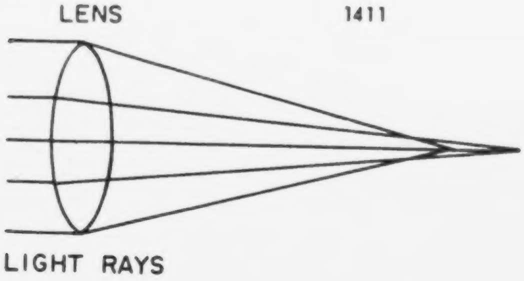


Figure 1-31. Spherical aberration.

121

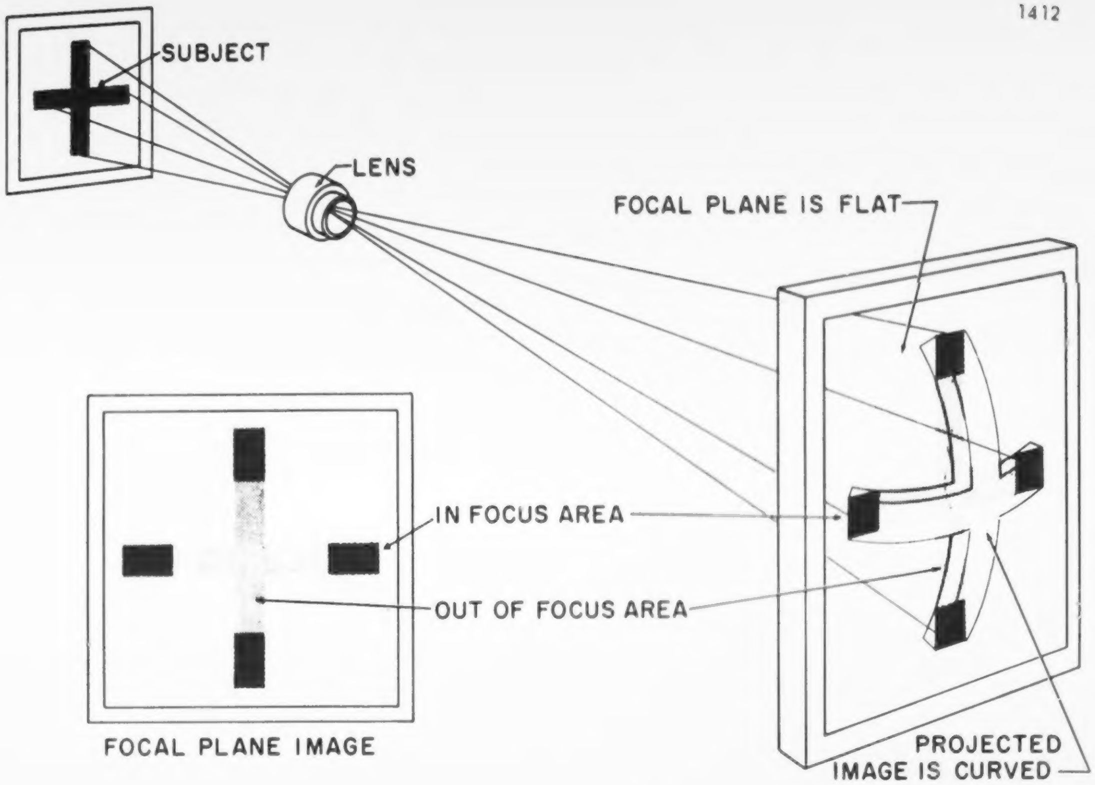


Figure 1–32. Curvature of field.

Flare. There are two general types of flare: mechanical and optical. Mechanical flare is caused by reflections that occur because of reflective surfaces on the inner side of the lens barrel, the camera, or anywhere else near the lens. Normally it is not an inherent characteristic of the lens, but the result of a damaged or burnished surface. Light coming from the subject reflects from such surfaces instead of being absorbed and is reflected onto the film. Such flare can be eliminated by coating damaged surfaces with a nonreflective coating.

Optical flare results from internal reflections from the glass-to-air surfaces of the lens itself. Optical flare is not classified as an aberration, and it is present to some extent in any lens that has more than one element. Generally speaking, the more complex the lens, the greater the amount of optical flare. This is because of the greater number of glass-to-air surfaces.

The effects of flares are varied. Optical flare tends to cause ghost images that aren't critically sharp on the focal plane. It also reduces the image contrast at the focal plane. In addition, the images are of different size than the principle image. Mechanical flare tends to cause circular patches and a reduction in image contrast. Figure 1-34 shows the two conditions. The problem of optical flare has been greatly reduced by the technique of coating lenses, as you will see next.

Exercises (207):

1. What lens aberration probably caused the image discrepancies?

   a. A copy negative that is not in sharp focus at the edges.

   b. A negative in which the images at the edges appear to be elongated.

   c. Decreased subject contrast in a negative.

   d. A color transparency in which the blues seem to be out of focus.

   e. Two copy negatives of the same subject, one in which the top and bottom are out of focus, and the other in which the sides are out of focus.

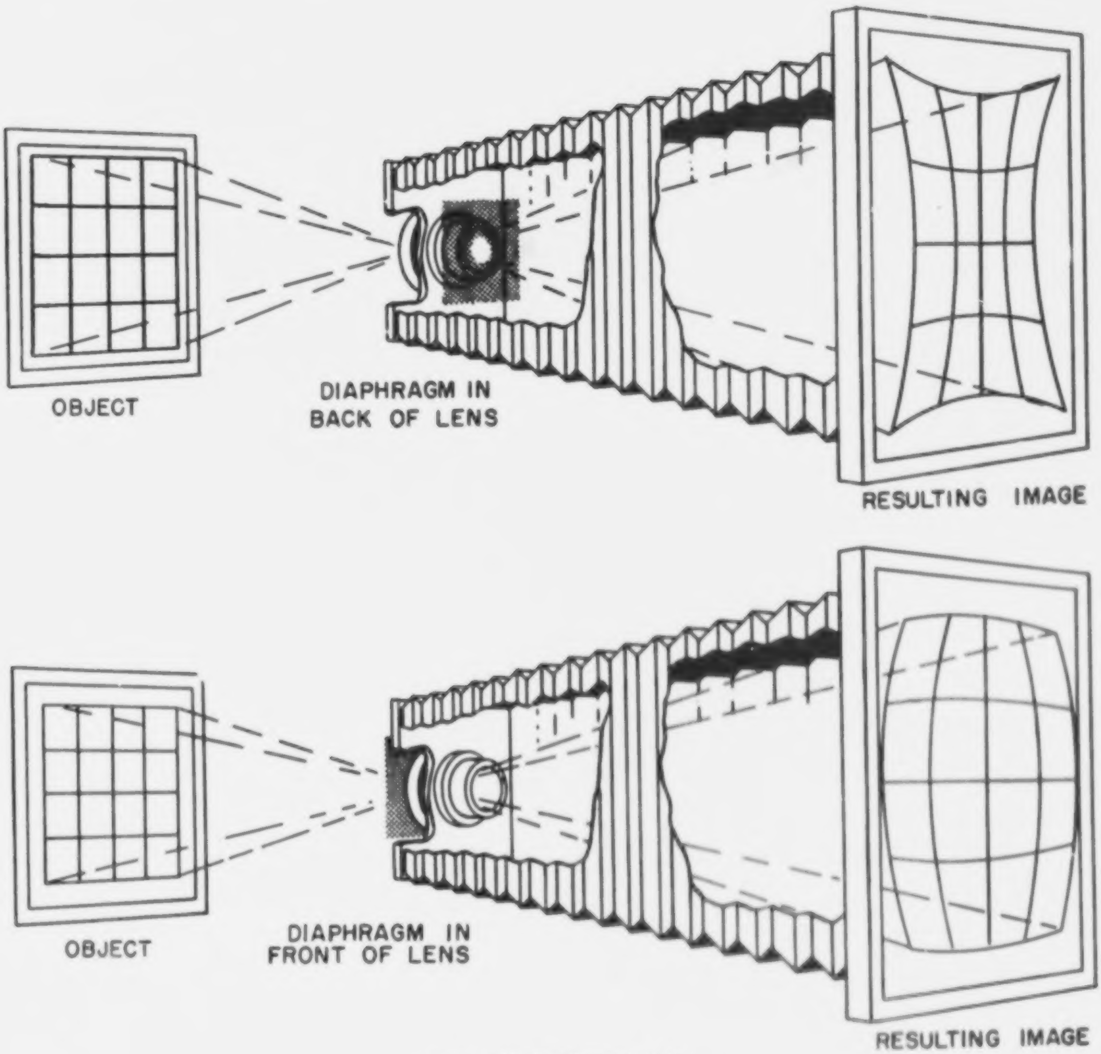

OBJECT
DIAPHRAGM IN
BACK OF LENS
RESULTING IMAGE
OBJECT
DIAPHRAGM IN
FRONT OF LENS
RESULTING IMAGE

Figure 1-33. Curvilinear distortion.

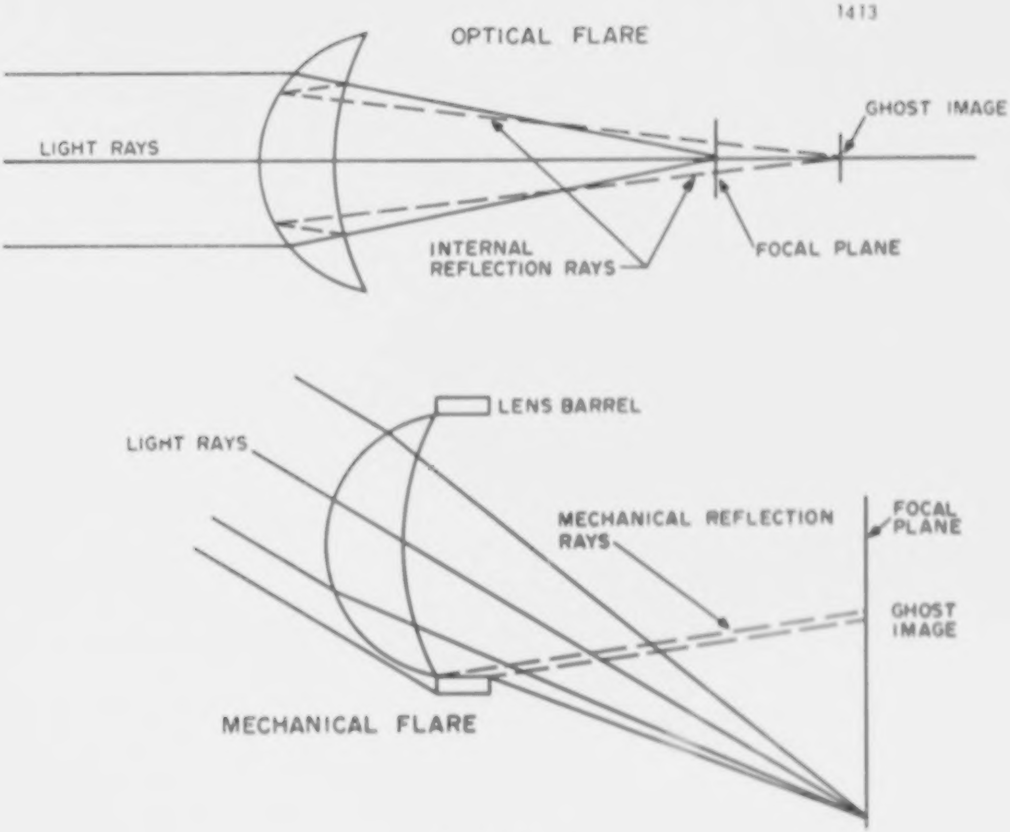

1413
OPTICAL FLARE
LIGHT RAYS
GHOST IMAGE
INTERNAL REFLECTION RAYS
FOCAL PLANE
LENS BARREL
LIGHT RAYS
MECHANICAL REFLECTION RAYS
FOCAL PLANE
GHOST IMAGE
MECHANICAL FLARE

Figure 1-34. Flare.

208. Compute the increase in light that will be transmitted by coated lenses as compared to uncoated lenses for given situations.

Lens Coating. Optical flare is especially prevalent in expensive lenses, because the amount of optical flare depends on internal reflections from curved, glass-to-air surfaces of the lens. The internal reflections increase with the number of reflecting surfaces. This problem has been practically eliminated since the practice of coating lenses has become a common procedure.

For many years, it had been known that old lenses which had become tarnished with a bluish coating actually transmitted more light than the new lenses. It is now common practice to coat new lenses with a layer or layers of transparent material having the correct thickness and refractive index. This coating minimizes internal reflections and thereby reduces optical flare. At the same time, the coating increases the lens transmission. The value of coating lenses is apparent as you compare the relative transmission values in this table:

No. of Lens Components	*Percentage Uncoated*	*Percentage Coated*	*Percentage Relative Increase*
1	91	98	8
2	84	97	16
3	77	96	24
4	70	95	35
5	65	94	45
6	60	93	55
7	56	92	66
8	51	91	80

At times, it might be beneficial to know the exact increase in exposing light you can get by using coated lenses. First, compute the amount of light reaching the lens. Let's use for our example 236 meter-candle-seconds (mcs). Next, compute how many mcs would be transmitted for the particular lens (uncoated) you have available. Let's assume that it is a 7-element lens. The actual amount of light that would be transmitted by the uncoated lens would be 236 mcs × 56 percent = 132 mcs. Now, for the actual increase in intensity that is possible by using a coated lens, we look at the table and see that there is 66 percent increase. Therefore, 132 mcs × 66 percent = 87 mcs in exposure.

Exercises (208):

1. Compute the approximate increase in light in mcs reaching the film plane when the lens elements are coated.

	No. of Elements	*MCS of Light Reaching the Coated Lens*
___ a.	5	145
___ b.	3	73
___ c.	1	76
___ d.	6	294
___ e.	4	163
___ f.	8	45
___ g.	2	190

1-3. Sensors

Since primitive people first realized the advantage of an elevated, unobstructed view of their enemies, the concept of reconnaissance has been part of physical combat. With the advent of the balloon, which was used during the Civil War as an observation platform, people no longer were dependent upon terrain to provide a vantage point. Furthermore, with the introduction of photography, they were no longer dependent upon memory to relay observations to companions on the ground. Thus, in the past century and a half, a new dimension has been added to reconnaissance. With the conquest of the air, and more recently of space, the scope of reconnaissance has leaped forward. An aircraft can survey hundreds of miles within a few hours. Space vehicles can do the same over thousands of miles within minutes.

Significantly, with the vast increase in coverage there is also an increase in the minuteness of detail which can be obtained. Through the use of one or more sensors, it is possible to detect virtually any movement of an enemy or a potential enemy, provided the sensor can be brought within range. The enemy, fully aware of this potential, must exercise elaborate precautions to hide or camouflage their moves from observation. The expanding array of sensors available makes this increasingly difficult. No longer is it possible to hide behind the hill, under cover of darkness or poor weather. These defenses have been penetrated by airborne day and night optical sensors, infrared, radar, and electronic reconnaissance.

209. State the purpose of the three basic components of an aerial camera.

Aerial Camera Components. In principle, the aerial camera is essentially similar to its ground photo counterpart. Its three basic components are the lens cone, body drive assembly, and film magazine (fig. 1-35).

Lens cone. The lens cone is a metal cone or cylinder that serves the same purpose as the bellows of a ground camera. Its purpose is to keep the lens at a specified distance from the focal plane. All aerial cameras are of the fixed-focus type, and focused at infinity. The lens cone normally contains the lens, the aperture, and shutter.

Body drive assembly. The body drive assembly contains the mechanism for the electrical and mechanical operation of the camera, which includes film transport, image motion compensation, camera mode selections, and attachments for the lens cone and film magazine. It may also contain a recording chamber, which identifies the mission for future use and storage. The chamber has a 24 hour clock, an altimeter, and a chalkboard with mission number, date, etc., which is photographed on the side of the film simultaneously with the normal aerial exposure.

Film magazine. The film magazine is usually detachable and is interchangeable with cameras of various types. The magazine uses a vacuum plate to hold the film taut across the magazine's rollers at the focal plane.

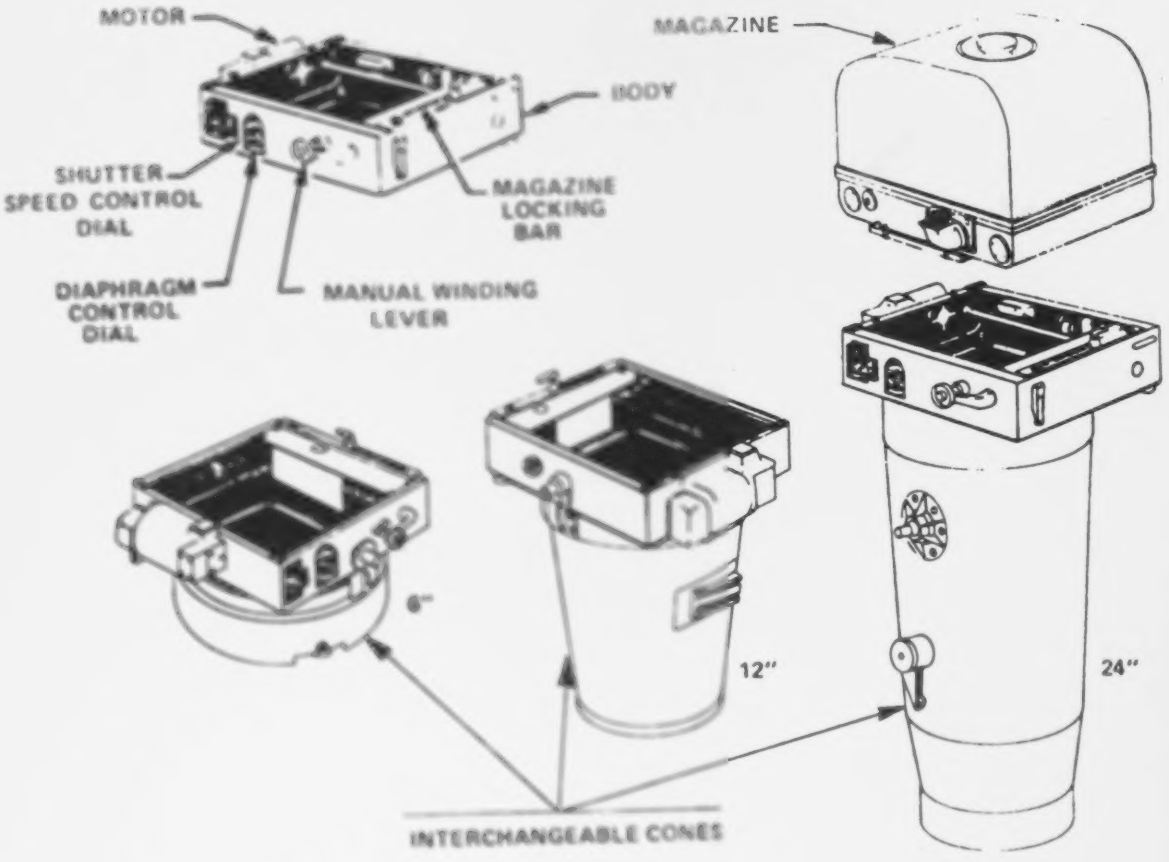


Figure 1-35. Aerial camera components.

Exercises (209):

1. What is the purpose of the lens cone?

2. Which aerial camera component contains a recording chamber for mission identification?

3. What is the function of the film magazine?

210. Name the three main types of aerial cameras.

Aerial Camera Types. Although a small amount of aerial photography is done with hand-held cameras, the practice is considered impractical for most purposes. Most aerial cameras are somewhat heavy and cumbersome to begin with, and when this factor is combined with even minor G-forces, a considerable strain is placed on the photographer. For stability required in most applications, aerial cameras are placed in fixed mounts in the aircraft, and systems have been devised for each type of mission. Also systems are designed today to include the aircraft itself, with the camera system being designated a subsystem. For tactical reconnaissance, particularly, these are usually modifications of conventional fighter aircraft. They normally carry no armament, and the basic fuselage may be extended or enlarged to accomodate the camera subsystem. Depending on the number of cameras and the positions, focal lengths, etc., the system offers a great number of combinations, or configurations, for various mission requirements.

Aerial cameras derive their name primarily by the way the film passes through the system, their position in the aircraft and how they are utilized. The three main categories of cameras are framing, continuous strip, and special format.

Framing. A framing camera holds the film in place by means of a platen, which is vacuum operated to keep the film flat and stationary during the exposure. The resulting frame from the exposure produces a black border around the area photographed, hence the name "framing camera" (fig. 1-36.) When a framing camera is used with the film parallel to the ground it is called a vertical camera. If the

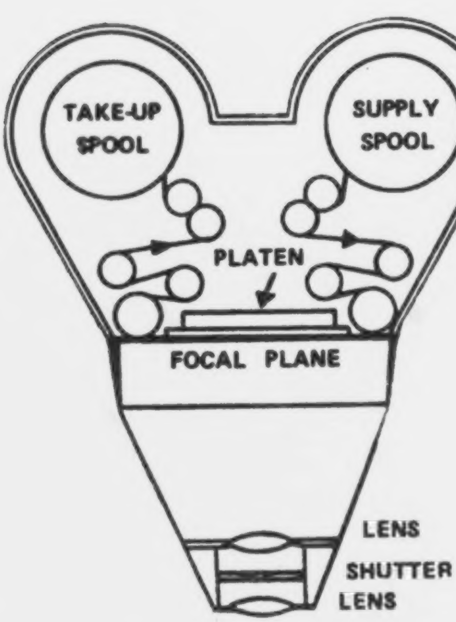


Figure 1–36. Framing camera.

film is not parallel to the ground it is called an oblique camera. The use of two or more framing cameras mounted close together is called a fan configuration. There may be two verticals or a combination of verticals and obliques. The framing cameras used on the "Phantom II" are the KS–87, with four different focal lengths, and the fixed focal length T–11 topographical mapping camera.

Continuous strip. The continuous strip camera was developed for low altitude, high speed missions. The film is passed continuously along the same direction as the aircraft's flight and the exposure is controlled by a slit aperture to stop the movement of the ground imagery. The image produced has borders only along the edges of the film and is therefore continuous.

Special format. Special format cameras employ principles of both framing and continuous strip cameras and are commonly known as panoramic or pan cameras. The pan camera may use a rotating prism to continuously expose the image onto the film, creating an overall image with extremely wide angles of view. The specific cameras used are the KA–91B high-altitude panoramic camera and the KA–56A low-altitude panoramic camera.

Other examples of aerial photography include use of the typical movie camera and gun camera as sensors.

Exercises (210):

1. What do we call a framing camera mounted with the film parallel to the ground?

2. What type mission is the continuous strip camera used for?

3. What is the principle behind the special format camera?

211. Distinguish among the three main types of camera installations used on the RF–4C aircraft.

Camera Positions. There are three main types of camera installations used on the aircraft: the vertical, the oblique, and the fan (fig. 1-37).

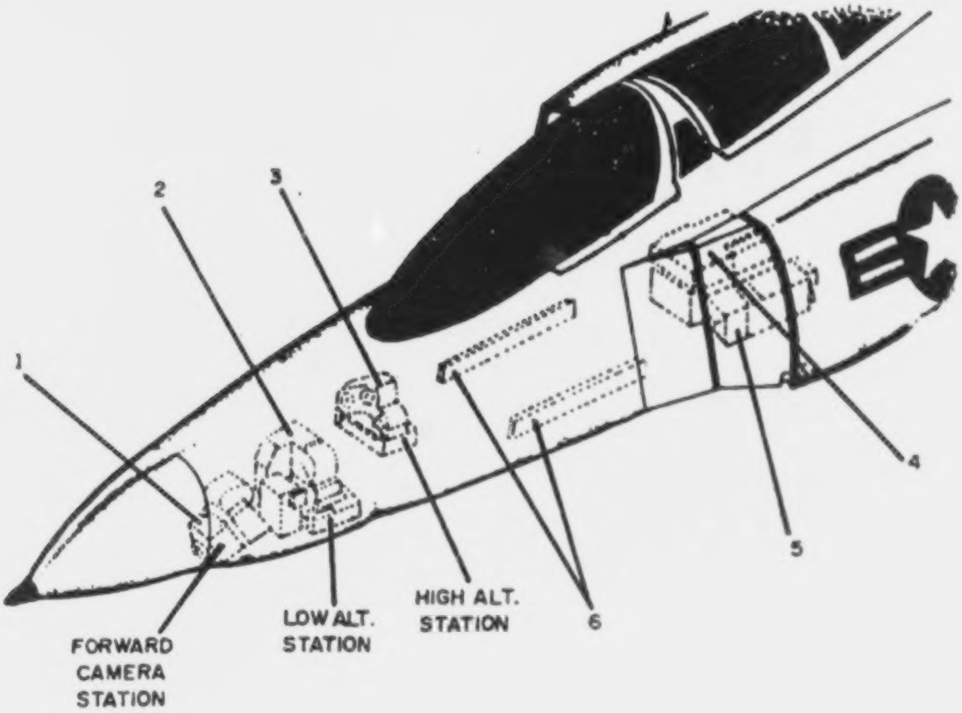
Vertical installation. The vertical photograph is an aerial photograph taken with the camera axis perpendicular to the earth's surface. Ground features appear in perspective with minimum distortion and relatively small errors in scale. Verticals provide excellent aids to crews on high altitude missions, providing a familiarity of the area being flown. Disadvantages are that verticals present an image seen from an unfamiliar point of view and they show a limited field of view. The major use of the vertical camera installation is to cover extensive areas for mapping. This is generally called area-cover photography and consists of a number of flight lines, which are usually overlapped. The individual photographs may then be assembled into a "mosaic." The vertical is also the prime sensor for night photography.

Oblique installation. Oblique photography is an aerial photograph taken with the camera axis directed intentionally between the horizontal and vertical. Therefore, the aircraft does not have to fly directly over the area to be photographed. A high oblique shows the horizon; a low oblique does not. A high oblique photo shows much more area than a vertical photo with the same focal length and from the same altitude, but the images grow smaller toward the horizon. Objects in the background tend to lose their proper perspective in proportion to the obliquity of the camera angle, to the extent that the correct horizontal plane of an individual object cannot be determined.

In oblique photos, the terrain appears as a conventional image rather than the map-like presentation of the vertical. Since oblique photos are more pictorial and more readily read, they provide excellent briefing aids for crews on low-level missions. One disadvantage of oblique photography is that scale diminishes from foregrown to the horizon. Calculations are also difficult, and they require trigonometry. Observation is limited to line of sight. In addition, oblique photography is not very effective at night.

Fan installation. There are three types of fan installations used: the split-vertical, the trimetrogon and the multicamera. The split-vertical installation (fig. 1-38) consists of two oblique cameras operating simultaneously and mounted so as to provide a small amount of sidelap.

Trimetrogon photography is used in search reconnaissance. It takes three cartographic cameras with 6-inch (152mm) wide-angle lenses. One vertical and two oblique cameras are mounted as shown in figure 1-39. The


1
2
3
4
5
6
FORWARD CAMERA STATION
LOW ALT. STATION
HIGH ALT. STATION

INDEX NO.		
1	KS-87 OR KS-72	FORWARD OBLIQUE OR NOSE VERTICAL
2	KS-87 OR KS-72	L & R OBLIQUES OR/AND LOW PANORAMIC KA-56
3	KS-87 OR KS-72	R & L Split SPLIT VERTICALS OR KA-55/KA-91 PANORAMIC
4	AN/AAS-18	INFRARED MAPPING RECORDER
5	AN/APQ-102	SIDE LOOKING RADAR RECORDER
6	APQ-102	RADAR ANTENNA

Figure 1-37. RF-4C sensor positions.

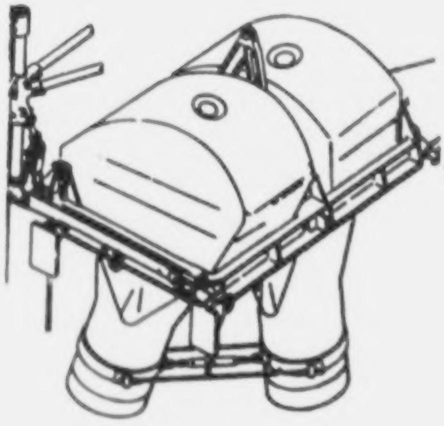


Figure 1-38. Split-vertical camera installation.

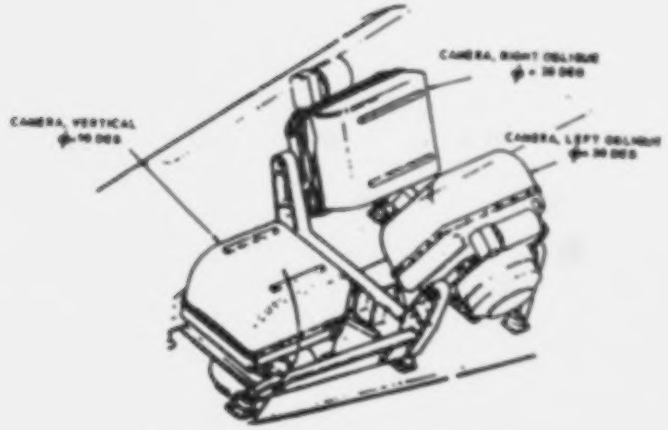


Figure 1-39. Trimetrogon camera installation.

center camera is vertical, and the oblique cameras are opposing each other at 30° depression angles. This gives horizon-to-horizon coverage.

The multicamera installation consists of three or more cameras mounted so as to provide a small amount of interlock between adjacent photographs for continuous extended lateral coverage. Installations with an odd number of cameras include a vertical in the center. Those with an even number fan out from the split-vertical. A typical multicamera installation is shown in figure 1-40.

Exercises (211):

1. What are two main disadvantages of the vertical camera position?

2. What is an oblique photograph?

3. How does trimetrogon photography work?

212. State how two nonoptical imagery systems are used on an RF-4C aircraft.

Nonoptical Imagery Systems. Besides the camera systems, there are other sensors in the reconnaissance aircraft that supplement the optical sensors and provide information that aerial cameras cannot produce. Two nonoptical sensors are side-looking airborne radar (SLAR), and infrared sensors.

Side-looking airborne radar. Side-looking airborne radar (SLAR) produce radar imagery whose range and ground resolution is far superior to earlier airborne radars. Its high resolution capabilities make it a useful all-weather, day or night mapping and reconnaissance tool. (The term "high resolution" is used in comparison to common bomb radars and not to photography.) This type of radar is termed "side-looking" because it transmits the radar beam at right angles to the aircraft. Thus, the radar antennas "look" to the sides of the aircraft.

A radar beam is sent from the aircraft to the ground and bounces back according to the ground features. This returned signal is converted into light by means of a cathode ray tube (CRT), which is similar to a television picture tube. A photographic data film is passed over the CRT and exposed. At the completion of the flight, the data film is processed and placed in an optical correlator. This machine acts as a printer and unscrambler of the information recorded on the data film. This optical correlator uses the data film to expose a final image map film, which is then processed and used normally.

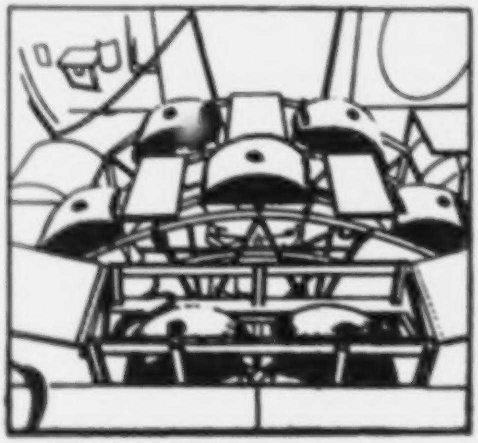


Figure 1-40. Multicamera installation.

Infrared. A combination of the optical and radar sensors studied so far does not meet all the requirements for an ideal reconnaissance system. There's another sensor system available that uses natural infrared radiation to help cover some of the missing requirements.

All objects radiate infrared energy. There are many sources for this energy with the sun being the prime one. The infrared sensor can record this radiation. As an object radiates infrared, the airborne sensor picks up the radiation and focuses it into an electronic unit. This unit converts the infrared into an electronic signal, which is projected onto panchromatic film through a CRT. The film is then processed normally at the end of the mission. It takes a skilled interpreter, however, to use the images recorded by the sensor. The interpreter must understand the nature of infrared energy and the physical laws that govern its behavior. Also, the image is greatly affected by natural, mechanical, and environmental factors.

Exercises (212):

1. Why is (SLAR) called slide-looking radar?

2. How is infrared radiation recorded?

1-4. Black-and-White Film Emulsions

You must have detailed and accurate information about the transparent-base, sensitized materials commonly referred to as film to help you make better decisions in selecting material for the job. This knowledge should also help you do a better job of processing, especially when you are confronted with some specialized type of sensitized material with which you are not familiar.

From your previous training and experience, you should know the basic structure of transparent, sensitized materials. As you know, a piece of sensitized material consists of a number of different layers, or parts. These parts normally include the overcoating, emulsion, substratum coating, base, noncurl backing, and the antihalation dye (within the base or within the noncurl backing). It is the aim of this section to give you a greater understanding of these various parts of sensitized materials. The more you know of the structure, the better processing job you can do.

213. List the steps in making photographic emulsions and state the step in which to determine the grain size.

Sensitized Materials. With the continued expansion of precision engineering photography, research and development photography, instrumentation photography, extremely high-altitude photography, etc., fresh demands continue to be made on the film manufacturers. They, in turn, respond with new and better products. The manufacturing process, however, remains fundamentally the same. Essentially, the process has six steps: emulsification, first digestion (ripening), wash, second digestion (after ripening), emulsion finishing, and coating.

Emulsification is the process that puts the silver halide into the gelatin. The ingredients and the way they are put into the gelatin solution do much to determine the final character of the emulsion. Slow chloride emulsions are made by rapidly adding the *unwashed* chemicals to the gelatin. This has the effect of producing small, uniform crystals. The faster emulsions are often produced by slowly adding the *washed* chemicals to the gelatin. This has the effect of producing larger, more sensitive crystals.

First digestion, sometimes called ripening or first ripening, includes heat treatment. Where solvents such as alkaline halides or ammonia are present, an increase in temperature causes the smaller halide crystals to be dissolved and plated onto the larger ones. This process is known as Ostwald ripening; it produces fewer, but larger, more sensitive crystals.

Washing is a critical operation in emulsion manufacture. The wash water must be free of organic or metallic substances, which might affect the gelatin or cause fog, and the washing time must be accurately controlled. Emulsions for various purposes are washed for different periods of time. (For example, emulsions for paper are washed very little and sometimes not at all.) The usual practice in washing is to force the emulsion, in the form of a hydrogel, through a screen, which cuts it into strips. This makes it possible to get controlled washing in a relatively short time. A recently developed alternate method of preparing the emulsion for washing precipitates the emulsion into a mass resembling cottage cheese and then washes it. One advantage of this method is that the emulsion can be washed in less time.

Second digestion, or *after ripening,* is another heat treatment, but its effect on the grain size or the size-frequency distribution is not as marked as the effect of the first digestion. The bulk of the gelatin is added at this stage.

Emulsion finishing is the step that usually adds color-sensitizing dyes, antifogging agents or stabilizers, preservatives, and materials to make the emulsion more flexible (to promote easier coating). If the emulsion is to be used for making positives, substances are also added to control the color of the image.

Coating the support is the final step in the manufacturing process. The thickness of the coating is controlled by the viscosity of the emulsion. A low-viscosity solution makes a thin coating. As the viscosity of the emulsion increases, the emulsion deposit gets thicker and heavier.

Exercises (213):

1. List the steps in making photographic emulsions.

2. During which step of emulsion making is grain size determined?

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214. State the reasons for the physical, optical, and chemical requirements of film base materials.

Base Materials. As an experienced imagery production specialist, you are undoubtedly well acquainted with the type of film base called *cellulose acetate*. There are many other kinds of emulsion supports, including paper and glass. At this time, we are concerned with base materials that are transparent.

As you know, a satisfactory base must be strong but not brittle; it must not tear easily; and it must maintain certain flexible qualities over a long period of time. In addition, the base must be free from curl and must not buckle in use. In other words, the base must allow the film to lie flat during the moment of exposure.

In the area of physical qualities, one of the most important factors is dimensional stability. You can imagine what could happen to the reproduction of an extremely small object if it were produced on a film that was dimensionally unstable. It would surely be inaccurate. Also, the problem of dimensional instability is further complicated when any of the untrathin base materials are used.

Finally, other physical (or thermal) requirements are that, for safety reasons, the film base is slow burning and it may be processed at higher-than-normal temperatures without damage. High-temperature processing is used so often in processing rush work that it should be considered when any mission is being planned.

In addition to the physical characteristics of a base, you must also consider the optical qualities of the material. The base (in most cases) must be transparent and free from any haze or any other imperfections. Unless some type of antihalation dye has been intentionally added, the base must be virtually colorless. The color of dye, if present, is an optical factor.

There are also chemical characteristics of the base material to be considered. Since the film is subjected to immersion in various chemical solutions, the base must be resistant to chemical action. Also, the film base must be inert to the chemicals in the emulsion coated on it. Since it is subjected to immersion in solutions in which the common solvent is water, the base must be resistant to moisture. Finally, the base must be able to hold the emulsion to its surface under various processing conditions without frilling.

Looking at these requirements, you can see that both the manufacturer of the film and the photographer who uses it must consider many different things in choosing the best material for a specific job. Since no one base material is perfect for all conditions, the result is usually a compromise. The choice usually depends on which base material requires the least compromise to produce the best image.

Exercises (214):

Why is each of these a requirement of film base materials?

1. Dimensional stability.

2. Slow burning.

3. Transparent.

4. Resistant to chemicals.

215. Relate undesirable film characteristics to the absence or presence of the film layer that resulted in these characteristics.

Substratum Coating. Trying to put an emulsion directly on top of a film base is about like painting a glossy enamel on a surface that already has a glossy finish. Most new paint tends to peel of in a short time. In film, the emulsion does not adhere to film base without a subcoating. If the subcoating is not used, the emulsion will frill off when it's wet or peel off when it's dry. For this reason, a substratum coating is required. The composition of the substratum coating is basically gelatin mixed with an organic solvent and cellulose acetate. The organic solvent binds the gelatin to the surface of the film base and binds the emulsion to the gelatin in the substratum coating. In other words, the gelatin in the emulsion adheres to the gelatin in the substratum coating, and the cellulose acetate of the substratum coating adheres to the film base.

Anticurl Coating. Usually film base is highly flexible, and when the base is coated with a gelatin emulsion on only one side, the unequal expansion and contraction of the emulsion and the base cause the film to curl. This curling tendency is overcome by coating the opposite side of the film with an anticurl coating. Generally, this is a coating of gelatin, a coating of cellulose esters, or sometimes solvents. Because they reduce static electrical discharges caused by film movement, the cellulose esters are especially valuable.

Overcoating. In some cases, film is also treated with an overcoating, sometimes called a nonabrasion coating. Very often, when an emulsion is subjected to stresses, abrasive action, or surface friction, the unexposed silver halides become developable. Sometimes, exposed halides are densensitized to a small degree. The overcoating, which prevents these actions, is simply a thin protective layer of gelatin.

Exercises (215):

In each situation, state which film layer is defective or missing.

1. Irregular dark streaks in processed film as a result of friction between the film and film magazine rollers.

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2. Regular streaks of either increased or decreased density.

3. Processed negatives that have many areas where the emulsion is missing.

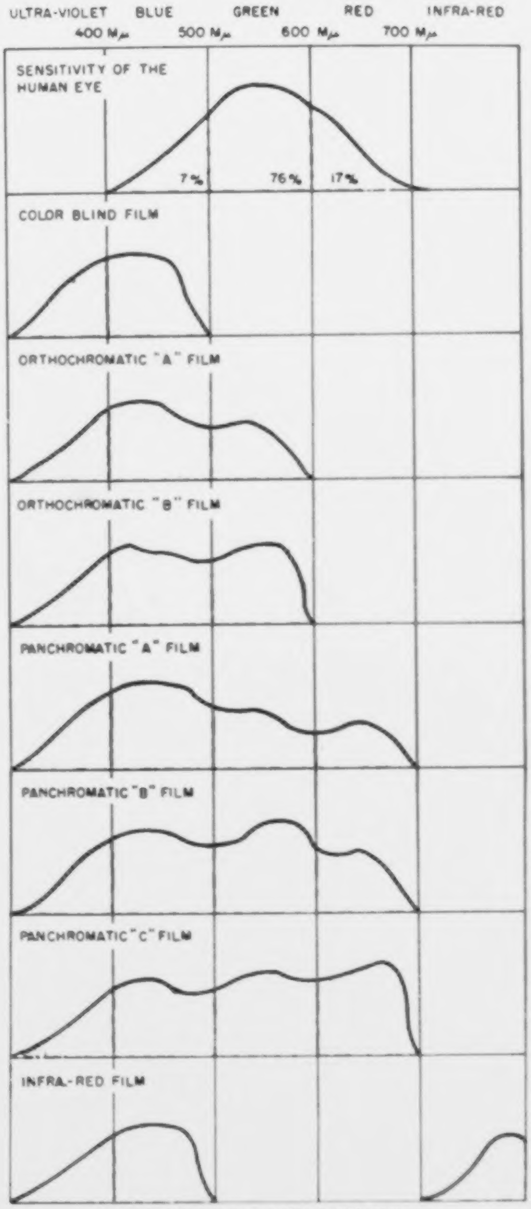
216. Relate given color sensitivity characteristics to specific film emulsions.

Emulsion Characteristics. Film emulsions differ in the way they react to the light that falls on them. If you know how the various films react, you can make a proper choice of film to meet the requirements of any specific mission. Starting with color sensitivity, let's look at the important emulsion characteristics.

Blue-sensitive emulsion. When photographic emulsions were first made, manufacturers did nothing to change the sensitivity of silver halides. Since silver halides are sensitive only to blue light and to ultraviolet radiation, which is invisible to the human eye, these films were affected only by the blue portion of the light. Blue-sensitive films are not used for general photography today, but they still have a definite place in photography.

Since this earlier film was not sensitive to green and red, results were not always the best. For example, the sky area of a scene taken on a clear day is quite blue. This means that the sky would produce a heavier exposure on blue-sensitive film than the other areas of the scene. The sky would be quite dark on the negative and, when the negative was printed, the sky would come out white. Also, the green and red objects of the scene would produce relatively little exposure on the negative and, consequently, would be quite dark on the print. This discussion might lead you to believe that the print made from blue-sensitive film was composed of nothing but solid blacks and pure whites. This is not necessarily true, since there are no so-called pure colors in nature, and you can expect a certain percentage of blue to be reflected from other colors of the subject. Thus, the blues are reproduced too light, and the other colors are too dark, but they are shades of gray—not just black and white. Photographs of this type were good for their day, but newer emulsions now give better results. Now you can correct the color distortion in the tones of gray that were so noticeable with blue-sensitive film.

The blue-sensitive emulsions were also slow in speed. You can see the reason for this by referring to figure 1-41, which compares the color sensitivity of typical films to that of the human eye. Blue-sensitive film is sensitive to about one-third of the total visible spectrum, which, to a great degree, accounts for its slow speed. In other words, to make a good exposure on this film, you need a lot of light or long exposure. Do not, however, get the idea that this type of emulsion is not useful. It is still manufactured because it yields the high-contrast results needed for copying black-and-white subjects, such as line drawings, charts, pages from books, etc. High contrast, in this sense, means that the subject is composed of blacks and whites with no intermediate gray tones.



COLOR SENSITIVITY OF FILMS

Figure 1-41. Color sensitivity of film.

Orthochromatic emulsion. Eventually dyes were added to blue-sensitive emulsions to make the silver halides sensitive to green light as well as to blue light. This film was named orthochromatic (true color) because its users felt it was the ultimate in color sensitivity. The term was incorrectly applied, however, since the emulsion is not sensitive to red and does not reproduce red in its correct shade of gray.

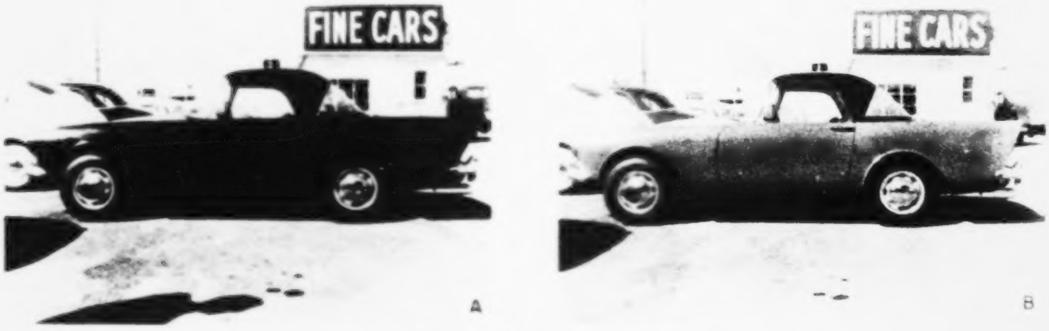


Figure 1-42. Orthochromatic and panchromatic film.

Ortho films as they are often called, are made in several speeds and variations in the amount of their color sensitivity. They are excellent for many uses, if we consider their incorrect rendition of the color red when we photograph the scene. Since they are not sensitive to the color red, red light does not (for practical purposes) make a latent image on the film. Therefore, after processing, red objects are relatively transparent on the negative. This means that they are quite dark on the print. As an example, ortho film is good for a portrait of a man, but if you used it to photograph a woman wearing makeup, the light reflected from her red lipstick would look much too dark (almost black) on the print.

Figure 1-42,B, shows the response of ortho film, photographing a red automobile with a black top. Notice that the top is quite dark and the body of the automobile is a medium shade of gray. These shades of gray are just about what you would assume to be correct. Now, look at part A of this same figure. This is the same automobile taken under the same lighting conditions, but using panchromatic film. Since this film is not sensitive to red, the body of the automobile would be almost clear on the negative. Since the top is black, it too would be clear on the negative. Reverse these tones on the print, and you can see that the red body of the automobile is practically as black as the top. Thus, the film has made no distinction between red and black, and the viewer of the photograph could presume that the entire automobile was black.

Panchromatic emulsion. Some years after the development of orthochromatic film, additional dyes were added to emulsions to make silver halides sensitive to the red light in addition to blue and green lights. The term "panchromatic" (meaning all-color) was given to this new film. The automobile shown in part B of figure 1-42 was photographed on film of this type. "Pan" film records most colors in their relative tones or shades of gray. Even though pan film is sensitive to all colors, it does not reproduce them in the same tonal values that the eye sees. Of the three primary colors, green appears brightest to the eyes (fig. 1-41). Yet, the color green photographs darkest on the majority of pan films. This effect can be modified to some extent through the use of photographic light filters. Filters are used to change the sensitivity of the film by allowing only certain portions of the visible spectrum to fall on the film.

Infrared emulsion. The diagram in figure 1-41 shows the color sensitivity of various films. Figure 1-43 is a more accurate diagram, called a *wedge spectrogram,* showing the sensitivity of infrared film. This emulsion is one that has been specially sensitized to the infrared region of the electromagnetic spectrum. Note that sensitivity extends into the invisible wavelengths beyond the visible red region.

Infrared film has many uses in scientific, investigative, and aerospace photography. One outstanding use for infrared film is aerial reconnaissance photography, because it gives sharp definition and good tone differation of distant objects under adverse climatic conditions. It penetrates haze because infrared is scattered considerably less than visible light. Additionally, the film is useful in document

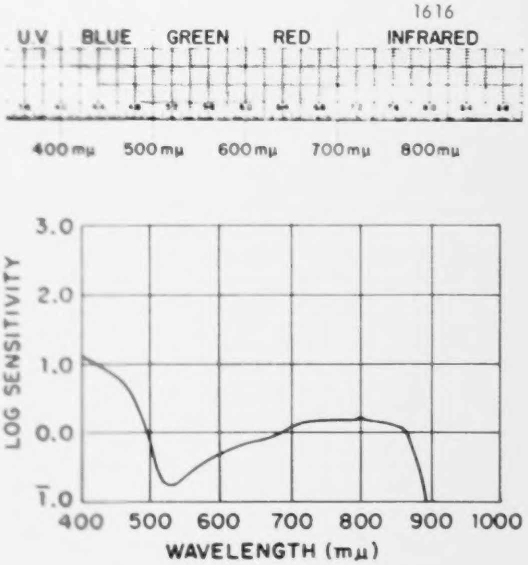


Figure 1-43. Wedge spectrogram.

photography, microphotography, and in many other scientific fields. In addition to its use in aerospace photography, infrared film is widely used in the field of medicine. For example, it is used to record comparative temperatures of different parts of the human body.

Infrared film is used to photograph terrain that contains artificial, dead, and living (green) foliage. You would think that the color green would produce very little exposure on an infrared film. This is true if the subject is painted green or if it has dead but still green foliage. In the case of natural and living green foliage, though, the chlorophyl in the leaves reflects infrared radiation to a high degree and, consequently, produces a heavy exposure. Thus, green trees are almost white in a print made from an infrared negative. You can see that the film is quite useful as a camouflage detection device.

Again, look at the wedge spectrogram of infrared film. Notice that even though the film has been sensitized to infrared, it still retains the basic silver halide sensitivity in the ultraviolet, violet, and blue regions. From this you can deduce that exposure to white light causes an exposure to more than just infrared. For this reason, you must use a special filter to eliminate all visible light so that the film records infrared radiation only.

Exercises (216):

1. What type film would produce shades of gray that are proportional to different shades or brightness or red?

2. What type film would be used to obscure clouds in photographs with large areas of sky?

3. What type film would be used to detect diseased trees?

4. What type film is not sensitive to red color?

217. Given a list of camera exposures for a given film and scene, compute the new exposures when a new film of different speed is used.

Film Speed. Simply put, film speed means that some films are affected by light much more quickly than others. Film manufacturers have assigned a speed number to each film. The larger this number, the faster the film. The biggest advantage of knowing the film-speed number is that it lets you compare the speed of one film to the speed of another providing that all other factors remain the same. For example, if a film has a number that is twice that of another, it means that it is twice as fast. Or, putting it another way, it means that only half the amount of light is required to affect the faster film to the same degree. *Emulsion speed* is a photographic property of very practical importance to you, since it has a direct bearing on the exposure required to produce a good image.

Before placing a film on the market, the manufacturer must supply the user with some indication of its speed. This is done by assigning a number to the film. All exposure computation devices (whether they are exposure meters or exposure guides) are also calibrated in the film-speed number system.

As you know, a photographic film emulsion is a combination of silver halides and gelatin. These silver halide grains are highly sensitive to light, while others are less sensitive to light. If a company wants to manufacture a high-speed film, the emulsion coating must contain a larger proportion of the more sensitive grains. If the company were manufacturing a slow-speed film, the larger proportion of the silver halide grains would have to be those of less sensitivity. If a given area on a piece of film is exposed to light for a very short time, only the more sensitive grains are exposed, and the area is a pale gray after development. If the film is fast, it contains more of the sensitive grains, and the resulting gray is darker after development. With a given amount of light, the faster film always produces a darker shade of gray than the slower film. More silver halides are exposed and, consequently, are developed to black metallic silver.

The practical application of a film-speed number is rather simple. Let's assume that you have been using a particular film for a considerable length of time. In taking photographs with this film, you have found that under bright lighting conditions, photographing brilliant subjects, the best exposure is 1/100 second at f/22. Let's say the film is rated at a speed of 100. Due to circumstances beyond your control, you must switch to a film with a speed of 200. What does this mean to you? It simply means that the new film is twice as sensitive to light as the old one. To compensate for this increased sensitivity in relation to the previous example, you must use either the shutter speed or the diaphragm to make the necessary correction. The new exposure for this film under the same conditions of lighting could be, for example, 1/200 second at f/22 or 1/100 second at f/32.

As you know, you can use different shutter speeds and f/stop combinations as long as the same total amount of light reaches the film as is given by the basic setting. For instance, a basic exposure of 1/50 second at f/16 could be changed to 1/100 second at f/11 or 1/25 second at f/22 and the film would still receive the same total amount of light. Since 1/100 second is 1/2 the time duration as 1/50 second, you open the aperture one stop to f/11 in order to let in twice as much light to compensate for the change in shutter speed. These combinations of shutter and aperture settings will all give you the same amount of light exposure:

Shutter speeds:	1/400	1/200	1/100	1/50	1/25	1/10	1/5	1/2
f/stops:	5.6	8	11	16	22	32	45	64

An exposure of 1/2 second at f/64 will give the same total exposure as 1/100 at f/11.

Any film speed should be considered as an approximate value. Based on your experience, you should raise or lower this figure if your results consistently indicate overexposure or underexposure. The recommended film speeds published by the manufacturer are usually computed for average conditions and should be varied according to your particular working methods and equipment.

Exercises (217):

A given scene should be photographed at f/16 at 1/100 of a second shutter speed with a film rated at ASA 100. What would be the new f/stops if you changed to each of these film speeds without changing shutter speed?

1. 25.

2. 50.

3. 200.

4. 400.

218. State the probable emulsion grain size of specified film types.

Emulsion Grain Size. As you know, a photographic emulsion contains microscopic particles (grains) of silver halide. Because of certain processes during manufacturing, these grains clump together. This clumping characteristic determines the inherent size of the grain in any film. High-speed emulsions generally have larger grains than slow-speed emulsions. The grain size produced in a particular film is called its *inherent grain size*.

In addition to inherent grain size, processing also has a great effect in the control of grain. By using special processing techniques, you can keep the silver grains from clumping excessively during development. When the grain becomes apparent in the image, it is objectionable, and the negative or print is said to be *grainy*.

Films can be broadly classified into fine-, medium-, and course-grained emulsions. The manufacture of a particular film places it in a graininess category. Usually, regardless of the inherent grain of the film you are using, you will notice very little difference on a contact print. The size of the grains doesn't make much difference until you make an enlargement from your negative. Unless the grains are quite small, as they would be in a fine-grain film, your enlargement may have a mottled appearance. If you want high-quality enlargements, be sure to select a fine-grain film.

Exercises (218):

1. Would ASA 125, or ASA 50, film probably have the largest grains?

2. If you knew that a particular negative would be enlarged, would you use ASA 100, or ASA 200, film to photograph the subject?

219. State the probable resulting negative contrast for given situations.

Contrast. As you know, some photographic densities are black in areas of heavy silver deposits, some are white (transparent) and have virtually no silver deposits, and in between there are many shades of gray caused by varying amounts of silver. Closely associated with density is *contrast*, which is the density difference between the high and low densities.

A bright area of the subject reflects a great amount of light, causing a corresponding heavy density in the negative, called a *highlight*. A dark area of the subject reflects little light, resulting in a corresponding thin density in the negative, called a *shadow*. The subject brightness between these light and dark areas also registers in the negative as corresponding densities, called *middle tone* (or *halftones)*. Normal contrast is represented by a full range of densities including highlights, middle tones, and shadows. A high-contrast negative does not have a full range of densities and consists primarily of highlights and shadows with few or no intermediate shades of gray. On the other hand, a low-contrast negative's highlights and shadows have very little difference in their densities.

The difference in contrast or variation in tones of gray results from several factors. The lighting on the subject affects contrast. The reflectivity of the objects in the scene affects contrast. The development of the film helps determine contrast, and the printing paper used has an effect on contrast. These are some of the external factors. A built-in factor that concerns us is called *inherent contrast*. Films are broadly classified according to their inherent contrast-producing ability. We can call them *low-contrast*, *medium-contrast*, and *high-contrast* films. The contrast of your final print is, in a large part, dependent on your choice of film.

Let us restate what we have said. Think in terms of high-contrast, medium-contrast, and low-contrast film. First, high-contrast films produce negatives in which the contrast between light and dark is higher than it seemed in the subject. Second, films of normal or medium contrast produce negatives in which the contrast between the light and dark is very similar (but reversed of course) to the original subject contrast. Finally, films of low contrast produce negatives in which the contrast between light and dark is considerably less than the original subject contrast.

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Remember that the shades of gray as they are reproduced on the negative and its subsequent contact print can be changed or altered by factors other than the inherent contrast of the film. Regardless of the contrast range of the film you have used, contrast always depends partly:

- Lighting conditions—lighting that produces brilliant highlights and dark or black shadows always produces a negative of higher contrast than if the scene has been illuminated with shadowless lighting such as open shade.
- Subject contrast—regardless of the film you are using, subjects of a high contrast always produce higher contrast negatives than subjects of low contrast.
- Exposure—overexposure and underexposure both tend to produce lower contrast negatives than correctly exposed negatives.
- Development—longer-than-normal development increases negative contrast and shorter-than-normal development reduces negative contrast.
- Developer—developers are also rated with respect to their contrast-producing effect. They are often referred to as high-contrast, medium-contrast, and low-contrast developer formulas.

In most instances, it is desirable to strive for normal results. Using a medium-contrast film with a medium-contrast developer, developing for the normal length of time, and making the print on a medium-contrast paper will (more often than not) produce a suitable result. For special purposes, you may find it necessary to vary any of the five factors (besides inherent film contrast) that control the final contrast.

You should now know what contrast is and how it may be changed. In most cases it is best to reproduce the subject as it originally appeared, and you can do this if you remember the variables that affect contrast. Be careful to avoid juggling these factors too much. For minor contrast adjustments, you can use printing papers of difference contrast.

Exercises (219):

1. If you photographed a scene of low subject contrast on a high-contrast film and then underdeveloped the negative, what contrast would the negative probably contain?

2. A low-contrast scene is to be photographed. The only film you have available is one considered to be of high contrast. Determine the probable negative contrast if you processed the film in:
   a. Low-contrast developer.

   b. Medium-contrast developer.

   c. High-contrast developer.

220. Define inherent latitude and exposure latitude.

Film Latitude. The ability of a film emulsion to record a range of subject brightness values is called *film latitude*. The range of brightness values in a scene that ends up on a negative or a print as shades of gray may be very great. If an emulsion can produce a long range of brightness values with satisfactory tone separation, it has *wide latitude*, but if it can produce only a short range of brightness values it has little latitude. This is *inherent latitude*. That is the latitude that is built into an emulsion. Inherent latitude is often considered to be an exposure safety factor. The extent that the exposure can deviate from normal and still give you an acceptable image is known as *exposure latitude*. Exposure latitude is directly proportional to film latitude. If you have film with wide latitude, you have wide exposure latitude. Thus, there is not just one correct exposure but several possible exposures that can render printable negatives. As long as the tones in the scene maintain their same relationship, your exposure is correct insofar as latitude is concerned.

Exercises (220):

1. Define inherent latitude.

2. Define exposure latitude.

221. Apply given procedures of subject recording in order to state how it is influenced by latitude in specific instances.

Effects of Latitude on Subject Recording. Figure 1-44 shows a number of shades of gray. The upper shades of gray represent the shades of gray in a print made from the lower shades of gray, which represent the negative. The shades of gray labeled A′, B′, and C′ represent three shades of gray in an object, say three blocks of wood painted in different shades, while shades A, B, and C represent the corresponding shades on a negative. The object shades (A′, B′, and C′), which are also the print shades, are reproduced on a negative that can reproduce the range labeled x-y. This x-y range represents the total capability of the emulsion and may thus be called inherent film latitude. Also, the tones A, B, and C represent the result of a certain amount of illumination which fell on the subject and was reflected to the camera—the photographic exposure.

Now, let us see what film latitude can do for us. We mentioned that latitude provides a kind of safety factor. Let's increase the camera exposure and see what happens. As more light strikes the film, each of the blocks becomes darker on the negative. Let's say that block A gets one shade darker. In our scale of tone values, it moves one block to the right on the negative scale. After printing, block A is one shade of gray in the print. Since the exposure of A is increased, the exposure on B and C is also increased.

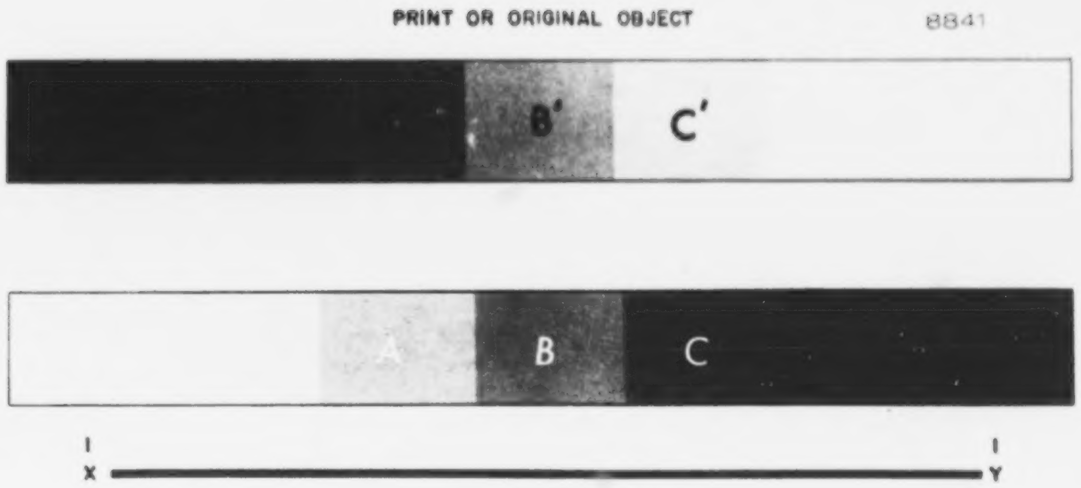


Figure 1-44. Film latitude.

Thus, B and C also move one square to the right on the negative scale. No harm has been done by this overexposure, since we are well within the shades of gray that can be recorded by our film. This is our safety factor. Using this same reasoning, you can increase the exposure even more and shift the original A, B, and C exposures two squares to the right and still produce acceptable results. This also applies to underexposures, except that the negative shades of gray shift to the left. If you go two blocks to the left on the scale of gray tones, you still get an acceptable print.

At this point, you may wonder what happens if you underexpose or overexpose to the extent that the film latitude is insufficient. As an example, consider an overexposure. If A, B, and C are moved two squares to the right, you are within the film latitude. Now try going three squares to the right. Block C moves to one square beyond the y position. Since the film cannot record anything darker than the shade of gray shown at y, C can only reproduce in the shade of gray shown at y. This means that in the final negative, blocks, B and C reproduce as the same shade of gray. Thus, instead of having a negative with tones A, B and C, you have compressed the range and have only shades A and B (C is the same as B). If you increase the exposure still more, A, B, and C all end up as the same shade of gray represented at y, and you have a total overexposure. For all practical purposes, the objects are black and reproduce as white on the print. This, in reverse, holds true if you move in the direction of underexposure.

You can see that there are several exposures, each of which can produce a printable negative if the scene is within the latitude. Usually, you would try to use the lesser exposures since heavier densities lengthen the printing time, cause possible changes of contrast, and often contribute to other deficiencies.

Exercises (221):

1. How does increasing the ratio of subject shadow brightness to highlight brightness affect the film latitude needed to record the subject?

2. You need a film that contains the greatest inherent latitude. Would you use low, medium, or high contrast?

3. A scene reflects light in the ratio of 4:200 (4-units from the shadow area and 200 units from the highlight area). Could you use a film that records ranges in the ratio of 1:50, or 1:4?

222. State the objective of resolving power measurements.

Resolving Power. If a film is given a brief exposure with an opaque, straightedged object placed in contrast with the film, after processing, the edge dividing the exposed emulsion from the unexposed portion appears sharp to the eye. But, under a little magnification, you can see that the line is irregular due to the granular image structure, or grain size. A longer exposure increases both the density of the exposed area and the difference in shade of gray between the exposed and unexposed areas. The line dividing the exposed and unexposed area now appears more diffused (fuzzy) than granular. The diffused appearance is caused by light scattering within the emulsion. The light is scattered into the unexposed areas by reflection from the silver halides in the exposed area of emulsion. If you increase the exposure still more, the diffused appearance of the line becomes more pronounced. Light scattering is usually greater in the fast, course-grain films than in the slow, more uniform, fine-grain films. Therefore, you can assume that films containing small regular grains in the emulsion produce sharper images.

The term "resolving power" is used to describe the inherent property of an emulsion to resolve (reproduce) fine detail in an image. Resolving power is expressed in terms of the number of lines per millimeter (a millimeter is approximately 1/25 inch) that can be individually distinguished in a photographic image. To make resolving power measurements, a resolving power target made up of line patterns is photographed. The smaller the distance (more lines per millimeter) between the individual lines that can be distinguished in the image, the higher the resolving power.

The resolving power of most films, with given conditions of exposure and development, increases with increased contrast. For example, black lines on a white background produce more resolving power than gray lines on a white background. Also, resolving power varies with the length of exposure, development, and other factors. Resolving power can be compared with several other characteristics of any film. It is affected by so many things that no one factor is significant, except when particular conditions are specified.

The majority of film manufacturers include with their products a data sheet that indicates, among other things, the resolving power. As with grain, if you want high-quality enlargements made from your negatives, you should select a film with a high resolving power. The manufacturer finds out how many lines per millimeter can be distinguished (as separate lines) in a photographic image by photographing a test target at a reduced scale with this film. The test target usually has a number of parallel lines separated by spaces of the same width as the lines. The photographic image of the test target is examined under a microscope to see how many lines per millimeter have been resolved. If the test target patterns have not been resolved, they do not appear to be individual lines but look like an indistinct gray mass.

Exposure influences resolving power. Resolution becomes less at high exposure levels. Correct exposure is especially important when you are using a miniature camera, since the prints from such small negatives are usually enlarged to a high degree. If you have overexposed, you have lost resolution, and the image on your print may not be sharp (edges of objects may be fuzzy).

Exercises (222):

1. What is the objective of resolving power measurements?

2. Can the absolute resolving power of a film be determined? Why or why not?

223. State the effects of handling and storing film under extremely high and extremely low temperatures.

Effects of Low Temperature. Usually low temperature does not cause very many problems associated with film. Most of your problems are with the functioning of equipment, but there are a few problems with film. At low temperatures, film becomes somewhat brittle and stiff, and emulsion cracks could occur. This is especially true when film must be unrolled from a 35-mm cartridge and rerolled on a takeup spool. Normal moisture content in the film helps reduce problems. With care, film used at temperatures as low as minus 60°F has produced acceptable results. Shrinkage and excessive curl may cause some problems, depending on the particular equipment used. Cold also increases the danger of abrasions and static electricity markings.

If you have taken high school chemistry, you may remember that cold slows down chemical processes. The reaction of film to the exposing (and developing) process is no exception. Film speed is reduced. As an example, at one time the Air Force conducted tests that showed that a film with a speed of 100 at normal temperature dropped to a speed of 40 at minus 40°F. Another film with a speed of 50 at normal temperatures dropped to a speed of 12 at minus 50°F. The drop in film speed, due to low temperatures, is best determined for a specific emulsion by trial and error as the occasion arises.

Effects of High Temperature. As the temperature of an emulsion goes up, the emulsion becomes softer and is more easily damaged by poor handling practices. Be especially careful when you're unloading holders and during any other handling prior to processing in a warm lab. In general, you can avoid handling defects by using proper techniques.

The primary consideration in protecting of film from high temperatures is proper care *not* during immediate use but rather *while the film is in storage*. Normal room, or outdoor, temperatures are easily withstood, but lower temperatures are advised for extended storage periods. Storage at 65°F. is adequate for conventional materials when there is a reasonably rapid turnover of stock. A moderately high temperature for a short time is not particularly destructive to film, but extended storage at high temperature does cause an overall fog. A factor in short or long storage periods, equally or more important than temperature, is *humidity* coupled with temperature changes. Humidity is the amount of water in the air at a given moment. We will discuss humidity in more detail later in this section.

We have mentioned previously that film speed drops at lower temperatures. The opposite is usually true as temperature rises. There is also an increase in contrast. You should note that temperature (and humidity) changes do not affect all film emulsions in the same manner or to the same degree. Also, any speed (density) or contrast increase is effective only to a certain temperature and time duration. As temperature, time, or both, pass a certain point, the increase in density and contrast are masked by an increase in fog.

Storage conditions to avoid, for even short periods of time, include hot, unventilated storage rooms or lockers, automobile glove compartments or trunks, and any other abnormally hot areas. Also avoid direct rays of the sun or high-intensity lamps. It is only too easy to lay a film holder on top of a camera case, window ledge, or similar surface exposed to direct sunlight. Since the holders are black, they rapidly reach extreme temperatures.

Abrasions. These markings are caused by film rubbing against another surface. The minute markings can eventually accumulate to the point where a negative is of no value. To see the effect of abrasions, look at slides or motion pictures that have been projected many times. The obvious care is to avoid subjecting film to needless handling and friction, whether the film is processed or unprocessed. Also, since dust particles are abrasive (like fine sandpaper), keep the film and surroundings as clean as possible. Exposed film unloaded from holders and laid on a dusty table provides a quick and easy method of generating abrasions, especially if you slide the film while it is in contact with the table.

Exercises (223):

1. List the effects of handling film at extremely low temperatures.

2. List the effects of storing film at extremely high temperatures.

224. State the effects of improper storage and preservation of common photographic films.

Humidity. The moisture content of the air is very closely related to temperature. If humidity and temperature are both improper, even a short storage period can cause pronounced image degradation. High temperature and excessive humidity in combination is common and may cause fog, provide an opportunity for growing fungus, produce transparent spots, etc. Excessive humidity and temperature fluctuation cause condensation of moisture. If moisture condenses on film, it causes many complications.

It is usually recommended that film be used and stored at never more than 60 percent relative humidity. On the other hand, a very low humidity and low temperature causes film to become dry and brittle and curl up. Most film is packaged by the manufacturer at 50 percent relative humidity. In general, humidity during storage is not a problem as long as the package seal is unbroken.

All sensitized materials are perishable, but color film is especially prone to damage. Store color materials under ideal conditions. As long as the film is retained in its regular package, humidity is not a great problem, but temperature should be maintained at 50°F. or less. Before using the film, you must let it come to room temperature in its unopened package to prevent moisture condensation on the film.

Latent Image Keeping. Certain problems arise concerning the length of time that the latent image can be retained. It is impractical to develop a piece of film immediately after exposure. Therefore, the latent image must be retained for at least a reasonable time. A sheet of film, after exposure, still contains the silver halides that were not used during production of the latent image. Thus, the film must be protected against any further action of light before development and fixation. Storage in a holder or cartridge is usually adequate if the container is lighttight, and not stored under bright light. The heat from a bright light may eventually produce fog, even inside a lighttight container.

Earlier, we mentioned the degree of humidity during storage of unexposed film. It is equally important here. Generally, the ideal storage of exposed film is the same as for storage of unexposed film. As a guide, tests have shown that a latent image can safely withstand a temperature of 75°F. and a relative humidity of 60 percent for about 3 days before any effect is noticeable.

Static Electricity. When one material, either positively or negatively charged, comes close to, or contacts, another material with an opposite charge, there is an electron transfer—a spark. This is *static electricity*, and it is especially bad under low-humidity conditions. You may have, at times, shuffled across a carpet, reached for a doorknob, and shot a spark from your fingertips to the metal. Such a spark close to a sheet of undeveloped film can expose the film. This exposure looks much like lightning.

Static electricity is caused by friction or by contact and rapid separation of materials. The best protection against it is to handle the film properly under conditions that minimize static electricity generation. All equipment should be grounded, and any film movements (removal from holders, respooling, etc.) should be slowed down to minimize static generation. If your laboratory area is quite dry, it may be desirable to humidify the air to about 40 or 50 percent relative humidity to reduce generation of static electricity. Fifty percent humidity is desirable, even if static electricity has not been a problem.

Exercises (224):

1. If the refrigeration unit for your film storage area doesn't work for 3 days, how might it affect the stored film?

2. What will happen if you open and use film immediately after taking it from a refrigerated storage area?

1-5. Black-and-White Print Materials

The quality of the image on prints is affected by your choice of printing materials, exposure, and processing. You can correct many of the deficiencies in a negative in the print. Because of this, it is important for you to have a working knowledge of all the materials you need to get the results you want.

The characteristics of printing paper are, in many respects, much the same as the characteristics of film. In this section we discuss some of the physical and emulsion characteristics you should be familiar with to produce better prints. You already know that printing emulsions are coated on an opaque base. The advantage of this is that you can view the prints by reflected light rather than by holding them up to a light as you did with negatives. Now, let's look at other sensitized paper attributes, starting with latitude.

225. Cite basic differences between film emulsions and paper emulsions.

Latitude. One of the prime differences between emulsion-coated paper and emulsion coated on film is that the paper emulsion layer is much thinner—and thinner emulsions have reduced latitude. A wide latitude for film is very desirable, but a wide latitude on paper emulsions could lead to many problems. A wide exposure latitude on paper is unnecessary, so correct exposure determination is simplified. In addition, a thick emulsion (such as that found on film) decreases image reflectivity. The paper emulsion must be thin, since light must travel through it, reflect from the paper base, and come back out. A thick emulsion would absorb too much light. Since paper emulsion has virtually no latitude, there is only one correct printing exposure. By using a series of test strips to determine the desired amount of light, you can readily find a correct exposure.

Exercises (225):

1. What is the main difference between an emulsion coated on film and one coated on paper?

2. What advantages are derived from the paper emulsion being thin?

3. What is the primary disadvantage of having thin emulsions on paper?

226. Name the three most common paper surfaces and weights.

Surface Texture. Printing papers are made with various surface (emulsion) textures. Those most commonly used are classified as glossy, semimatte, matte. Glossy surfaces are normally used where you want to retain all of the details possible from the negative. Glossy papers have a better tonal range than rough-surfaced papers, and the blacks are deeper and richer. It seems as though glossy prints have a more true-to-life appearance and much more sparkle.

Semimatte papers are best when you want to subdue extremely fine detail and minimize some graininess. Generally speaking, the semimatte surfaces should be reserved for the larger sized prints. If rough surfaces are used for small prints, some detail may be lost.

Matte papers are best suited for minimizing detail and the effect of graininess. Just as with the semimatte papers, matte surfaces should be used only on the larger sizes of prints, and they are especially desirable for producing image softness in printing portrait negatives. Matte surfaces are often produced in a number of variations that imitate the textures of such materials as canvas, tweed, silk, etc. By using a surface of the ''canvas'' type, you can make a photographic print look very much like a black-and-white oil painting.

Weights. Printing papers are made in various thicknesses (weights). When we speak of paper weight, we are referring to the thickness of the base material—not the thickness of the emulsion coating. The three most common weights the Air Force uses are double weight, single weight, and light weight. The choice of the paper weight depends on the purpose for which one plans to use the print. Double-weight paper is used mainly for very large prints. Single-weight paper is used for smaller sizes—up to about 8- by 10-inch prints. Light-weight paper is used when prints are to be folded or rolled (maps, documents, passports photos, etc.)

When you are deciding which weight to use, remember that washing and drying times increase with the thickness of the base. Sensitized papers with the thinner bases cost less and heavier bases are better for prints subject to considerable handling, but general recommendations can always be violated for specific purposes. Whenever you make changes in recommended usages, use good judgment.

Exercises (226):

1. What are the three standard printing paper surface textures?

2. What are the three standard paper weights?

227. Resolve problems with the emulsion speed and contrast of contact printing paper during printing.

Speed. The speed of a paper emulsion is relatively unimportant in selecting paper for a certain job. Most contact papers are relatively slow since they are usually chloride emulsions, and the exposing light supplied by contact printers is quite strong. Consequently, the emulsion speed should be slow. A second advantage of the slow speed is that safelight can be brighter without much danger of producing fog.

Since the speed of photographic printing papers is considerably less than that of negative materials, much more light must fall on paper to produce an exposure than must fall on the film to expose it. Many manufacturers publish relative speed values for their papers. These values are useful when papers are being used interchangeably in a darkroom. They help you determine exposures when you are changing from one type of paper to another.

Relative speed values are often published in the manufacturer's data sheet. They are not absolute values and require a certain amount of trial and error. From the data sheet, you might find that the paper you have been using has a relative speed of 2.5. You have established certain exposure times for average negatives printed on this paper. If you change to a paper with a relative speed value of 5, what does this mean? It simply means that the paper with a speed value of 5 is twice as fast as the one with a speed value of 2.5. Consequently, if your printing exposures were 10 seconds on an average, the new exposure time would be about 5 seconds.

Contrast. Contrast is one of the most important and useful characteristics of printing paper. The negatives that you will be printing will have varying degrees of contrast. If all subjects had the same degree of contrast and could be photographed under the same lighting conditions, and if all negatives could be given ideal exposure and development, then all negatives could be printed on the same sensitized material. However, this is not possible. Some negatives may be normal in contrast; any negative can be printed on "normal" paper, but the final print may not be the best possible print.

You must remember that film emulsions come in a number of different inherent contrasts. Not only can you change negative contrast by changing emulsions, but by changing the type of developer and time of development as well. On the other hand, the contrast of the paper emulsions is only slightly changed by manipulating development. Therefore, negative contrast must be compensated for by using printing materials that have a variety of inherent contrasts. The two common types of emulsions for controlling the contrast in the print are graded-contrast emulsions and variable-contrast emulsions.

Graded-contrast emulsions. Graded-contrast emulsions come in a variety of inherent contrasts so that you may fit the contrast of the paper to the contrast of the negative. The contrast grade of a paper emulsion is usually expressed by a number. Graded-contrasts are numbered 1 through 4 (although in a few cases, grades 0 and 5 are also available commercially). Number 1 contrast paper has the lowest inherent contrast and tends to lower the contrast produced from a given negative. Use grade number 4 where the negative is unusually flat or when extreme contrast is needed. For instance, you might use number 4 paper in reproducing a typeset page such as this.

The speed, or light sensitivity, of graded-emulsion papers varies with contrast (within a specific paper). That is, number 1 paper is the most sensitive to light and the sensitivity decreases as you go toward the higher numbers. Exposure compensation is necessary when you change from one contrast to another contrast of the same kind of paper.

Variable-contrast emulsions. Variable-contrast emulsions are so designed that within a single emulsion, there are available an infinite number of degrees of inherent contrast. Inherent contrast is controlled by the color of the light that strikes and exposes the emulsion. Graded-contrast emulsions are sensitive to the blue region of the spectrum only, and variable-contrast emulsions are sensitive to green and blue.

Variable-contrast emulsions are two emulsions on the same paper base. One emulsion is a blue-sensitive, high-contrast emulsion. The other is an orthochromatic, low-contrast emulsion with silver halides surrounded by a yellow dye to keep the blue and ultraviolet from affecting them. Consequently, the high-contrast emulsion is affected by blue light and the low-contrast emulsion is affected by green light. You get different contrasts by using filters over the light source.

Exercises (227):

1. You have been using a contact printing paper with a relative speed of 4. You switch boxes of paper, and the new paper also has a relative speed of 4, but the test print for the same negative is slightly darker than the previous prints. What probably caused this increase in density?

2. During contact printing you have a normal negative, but the test print on number 2 paper is too contrasty. What should you do?

228. State which variable-contrast filter to use in printing negatives of different contrasts.

Variable-Contrast Filters. After you have selected a variable-contrast paper (for example, Varigam) for your printing project, you must determine the contrast of the negative. A high-contrast negative takes a low-contrast graded paper and vice versa, but with variable contrast, you pick a filter that changes the color of the light in a way that makes the print emulsion print harder or softer.

Varigam filters, ranging from yellow (minus blue) to a purple blue (minus green), are available in either a set of 5 or a set of 10 filters. The set of five is all you need for average printing, because these filters produce results that correspond to the contrasts of graded papers available. A comparison of variable-contrast filters to graded-contrast papers is shown in table 1-1. For closer control of contrast, the 10-filter set includes the intermediate steps of numbers 2, 4, 6, 8, and 9.

TABLE 1-1
VARIABLE CONTRAST FILTERS

Number of Filter "Varigam"	Number of Filter "Polycontrast"	Comparable Graded Paper	Use With a Negative That Is --
1 2		* 0 (Very Soft)	Very Contrasty
3 4	1 1½	1 (Soft)	Contrasty
5 6	2 2½	2 (Normal)	Normal
7 8	3 3½	3 (Hard)	Flat
9 10	4	4 (Very Hard) * 5 (Extremely Hard)	Very Flat

* These Grades of paper are not normally stocked by the Air Force but are available commercially.

Varigam filters are balanced so that if you make a test print through a number 5 filter, the normal filter, and find the contrast too low or too high, you can change to a higher or lower filter number and use the *same* exposure time. The number 9 and 10 filters, which take approximately double the exposure for any of the others, are exceptions.

The filter colors start with yellow for the number 1 filter and gradually progress to peach and then magenta as more of the green light is absorbed in relation to the blue, until practically all the green light is absorbed in the number 10 filter, which is a purple-blue-colored filter. Remember that these filtration designations apply to Varigam papers, which are manufactured by E.I. du Pont de Nemours and Company. Filter material is available in sheets for use in contact printers.

The Eastman Kodak Company also produces variable-contrast papers called *Kodak Polycontrast* and *Kodak Polycontrast Rapid*. The basic difference between these two is the speed; the slower one is generally used for contact printing. The use of this material with respect to filtration is very much the same as for Varigram. The prime difference is in the name. The series has seven different filters that let you match the negative contrast with the proper paper contrast for a desired print. The filters are numbered from 1 through 4 in increments of one-half. Generally speaking, they produce a contrast that matches the corresponding number of graded-contrast paper. Thus, a print produced with a number 2 Polycontrast filter would have about the same contrast as a print produced on number 2 graded-contrast paper.

Variable-contrast paper is sensitive to blue and green light. Therefore, the Wratten series OA filter (yellow green) which is "safe" for graded-contrast paper *cannot* be used with variable-contrast paper. If this safelight were used with variable-contrast paper, it would fog the paper. The safelight filters recommended for variable-contrast papers are the DuPont S-55X or the Wratten series OC.

Some contact printers commonly used by the Air Force have argon exposing lamps. Since these lamps emit blue and ultraviolet radiation, they cannot be used for printing variable-contrast paper. You can modify this printer by installing white incandescent lamps of low wattage (to prevent excessive heat). Conventional 3-watt lamps such as those used in other standard printers are satisfactory. Variable-contrast filters for use with this type of printer must be in sheet form and placed on top of the ground glass.

If a considerable amount of contact printing using variable-contrast paper is to be done, you should use a printer such as the EN-22A. This printer is fitted with 3-watt incandescent lamps and Polycontrast filters by simply rotating the handles on the front of the printer. Both ends of the filter roll are clear so that you can eliminate the unneeded filtration when you're printing on graded-contrast emulsion.

Projection Papers. Because of the nature of the light source in projection printers, the distance between the light source and the sensitized material, and the existence of a lens between the light and the sensitized material, it is essential to use an emulsion that has relatively high sensitivity to light. Graded projection papers are usually coated with a fast bromide emulsion or a moderately fast chlorobromide emulsion. Chloride emulsions (used for contact printing) are just too slow to produce a print within reasonable exposure time limits. Graded-contrast projection emulsions are available and numbered in the same manner as graded-contrast contact emulsions.

You can use the same variable-contrast papers for projection printing that you used for contact printing. Contract printers adapted to use variable-contrast emulsions were fitted with low-wattage incandescent lamps. These low-wattage lamps were necessary in order to use the "faster" variable-contrast emulsions and to provide the white light needed for use with variable-contrast filters. Variable-contrast filters for enlarging are available in the same grades as for contact printing. For projection printing, these filters are available in 2-inch squares mounted in a rigid cardboard or plastic mount. A metal filter holder, to hold the filters under the lens, must be installed on your projection printer. Some Air Force projection printers have special filter holders installed that can simply be rotated to the correct filter; others have provisions for placing filters between the light source and the negative.

Exercises (228):

1. You are printing on Polycontrast paper with a number 8 filter. You use all available Polycontrast paper and must switch to graded-contrast paper. What grade would probably yield the same results?

2. Which Varigam filter should you use to print a negative with normal contrast?

3. You are given a negative to print that is flat in contrast. Which Polycontrast filter should you use?

4. Which Polycontrast filter should you use to print a negative with normal contrast?

229. Identify the environmental factors that affect the keeping qualities of sensitized materials.

Factors Affecting Sensitized Material Storage. Photographic papers are perishable and deteriorate with age. You must protect them primarily from the injurious effects of heat and moisture, as well as from harmful gases and from physical damage. Inadequate protection in storage causes increased fog, inferior tone reproduction, and a loss of emulsion sensitivity, distortion, and brittleness.

Certain gases, such as formaldehyde, hydrogen sulfide, sulfur dioxide, ammonia, and the exhaust from motors, damage light-sensitive materials. The vapors of solvents, cleaners, turpentine, and mercury can also contaminate photographic papers. In some cases they may even penetrate into cans sealed with tape.

Exercises (229):

1. What environmental factors affect the storage life of photographic papers?

2. What changes are evident in papers that have been subjected to unsatisfactory environmental conditions?

230. Give reasons for proper storage and preservation of common photographic paper.

Storage Criteria. Manufacturers package their products either for domestic use or for export. Materials intended for export or for use where high relative humidity is prevalent are packaged in moistureproof containers that are vaportight *and* watertight. Packaging for export is so labeled on individual units as well as on the shipping cartons. Materials intended for normal domestic use may be packaged in moisture-resistant, but not in watertight or vaportight containers. You should assume that any unlabeled package is intended for domestic use and handle it accordingly. Do not keep sensitized papers under refrigeration once the seal packages have been broken unless the refrigerator can be held at 50 to 60 percent relative humidity.

Store individual packages of film and paper on end so that the weight of the contents is on the edges of the film and paper. You should also store material with the earliest expiration date to the front of the stack. This lets you use the material with the earliest expiration date first. However, when you know that the paper that's due to be used next (according to earliest expiration date) has been shipped or stored under unfavorable conditions and you have a highly critical project to print, you should place this material aside and use fresh material to print this project.

Don't forget, paper removed from cold storage must be adjusted to room temperature before you open the packages, or you'll get moisture condensation. Bring the paper to room temperature over a period of at least 8 hours before use. Longer times are required for warmup if the packages are stacked.

Exercises (230):

1. Why shouldn't photographic facilities in oversea areas get photographic materials packaged for domestic use?

2. Paper that is taken from the cold storage area, opened, and used immediately will probably have small circles of different densities on the prints. Why?

1-6. Color Emulsions

Color films fall into two basic types: reversal and negative. Reversal color films, identified by the suffix "chrome" (Kodachrome, Ektachrome, Fujichrome, etc.), are processed to a negative, which then must be printed to produce positive prints.

Military uses of color materials have grown in importance. Many of the training films are shot in color to give more realism to the subject being taught. Engineering photography extensively uses color to bring out fine shades of detail, particularly wherever color conveys special information about the subject. An example of this application is seen in the research and development stages of rockets and missile engine exhausts, where the color of the plumes and patterns of the shock waves indicate the efficiency of fuel combustion as well as other details. Aerial reconnaissance missions use color films to examine areas suspected of having camouflaged stores or gun and missile launching emplacements. To bolster public morale, public information photography uses color to present service activities, as well as acts of mercy performed for flood-, tornado-, or war-ravaged foreign nations. By providing the public with pictorial facts, this type of photography helps counteract enemy propaganda. Thus, your laboratory may process one or more kinds of color photographs.

231. List the physical structure of typical color reversal emulsions and state the purpose of each layer.

Color Film Structure. It was over 30 years ago, that the first practical, single-base color material was placed on the market. Although from every angle the material appeared to have a single emulsion, its inner structure was actually made up of three distinct and different emulsion layers. Each layer responded to one of the three primary colors, even though all layers were coated on the same film base. The initial multilayer films were troublesome; because it was hard to get three images of reasonable sharpness. Silver halides scattered light rays in all directions throughout the emulsion layers, thus making it hard to get a red and green image record of acceptable sharpness. The use of stripping films as individual layers of emulsion, rather than separating the layers with relatively thick film bases, partially overcame the difficulty. While optical contact between the layers of emulsion was increased to make three images of acceptable sharpness, processing was complicated. Each stripping layer between emulsions had to be given its own support before the color process could be completed. Today most color materials consist of three thin coats of emulsion on a single film base. Each emulsion is separated from the next by an extremely thin interlayer of clear gelatin, which may be tinted to serve as a filter. Such color materials are known as multilayer films. Some films produce negatives for color prints, while others produce color positives through the reversal process.

Recall from your studies that all films are inherently sensitive to the color blue; the blue recording layer of emulsion is usually placed nearest the camera lens. This is normally the top or uppermost emulsion layer of a color film. Under the subtractive process of color photography, any positive made from the blue record would show density in all areas where blue light had not been recorded in the negative. Therefore, the positive printed from the blue negative represents the amount of yellow in the original subject. Blue has been subtracted by the original negative density, and the positive represents yellow—the complement of blue. This subtraction principle applies the same way to the other two primary color records.

A positive from the green negative represents the amount of blue and red in the original subject, so it is the magenta density. The red negative becomes the cyan positive because after the red has been subtracted from the subject, the only thing left is blue and green or cyan. If each one of these positives is dyed with the color complementary to the original filter and if all three positives are superimposed in register, the result is a transparency in color that represents the original subject.

A cross section of a typical piece of color film would look something like that shown in figure 1-45. Start at the top and work down. An antiabrasion coating protects the film from minor abrasions, but don't be fooled; a fingernail can very easily cut through this coating. The next layer down from the top is a blue-sensitive layer of emulsion, where the blue record is made.

The next layer is a built-in yellow filter. The purpose of this filter is obvious when you consider that the next layer must make a record only of green. The green-sensitive layer is an orthochromatic emulsion capable of recording both a blue and green exposure. Because of the yellow filter, however, only red and green light is allowed to penetrate to this point. Since this emulsion layer is not sensitive to red and since blue has been stopped by the yellow filter layer, the only exposure possible at this point is that which the green light produces. After the green exposure, another is made in the next layer, which is a panchromatic emulsion sensitive to red and with a very low sensitivity to green. Therefore, since the blue record can't penetrate to this point, only a red record is made.

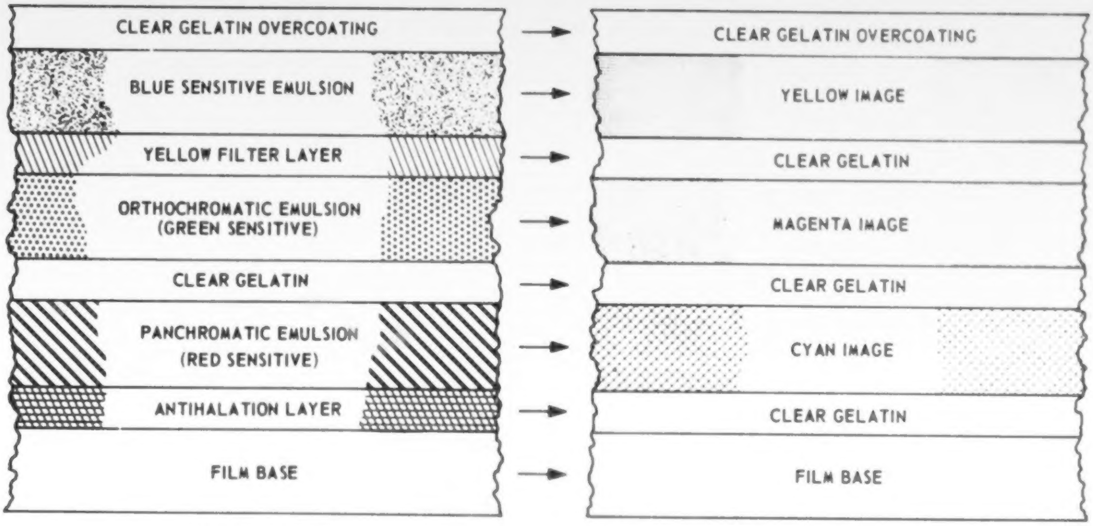
In effect then, a sheet of color film is made up of three separate emulsion layers, each one sensitive to or able to record only one of the additive primary colors of light.

Exercises (231):

1. What does each of the eight layers of reversal color film do?

232. State the characteristics that differentiate daylight color film from tungsten color film.

Color Balance. The two major divisions of color films are based upon the quality of the light to which the film is to



Undeveloped Film

Developed Film

Figure 1–45. Inner structure of color film.

be exposed—*daylight* or *tungsten*. To distinguish between daylight and various artificial light sources, we commonly refer to their difference in terms of color temperature. Remember, however, that color temperature refers to the color of light as seen by a human observer with normal eyesight. There is often a great difference between the effect of color as we see it and its actual photographic effect.

Color quality of illumination. A person becomes accustomed to the artificial illumination in a room, and the light appears to be white. The same room illuminated with daylight likewise seems to be illuminated with white light. However, if you turn on a tungsten lamp in a room that is illuminated by daylight, the tungsten light appears to have a yellowish cast. That which appears to be white may not be white, since the human eye is a poor measuring tool to determine the color quality of light. Thus, we need some method of measuring the color of what appears to be white light. One such method of measurement is the color temperature scale, expressed as *Kelvin* (formerly degrees Kelvin)—the temperature to which a blackbody radiator must be heated in order to emit light equal to a source such as tungsten lamps, the sun, etc. The scale starts at −273° Centigrade (absolute zero), which is designated as zero Kelvin. The scale has become universal in the measurement of color temperatures.

All tungsten or daylight sources are not at the same color temperature. Table 1-2 lists the commonly used light sources and their approximate color temperatures.

You probably recall that the effective film speed often changes when you switch from daylight use of a film to tungsten light. The reason for this change is the difference in the special quality of color content of the light. A change in film speed in black-and-white film usually compensates for a radical change in light quality, but this is not the case with color film; here, you must consider color temperature. Color film is in correct balance for only one type of light and should be used under specific light conditions. If these conditions change, then the colors you photograph appear degraded or out of balance. Normally, each manufacturer makes two types of color film—one to be used under tungsten light and the other to be used under daylight conditions.

A knowledge of color temperature is valuable, but the Kelvin (K) rating of a light source is not the only factor to consider. For example, two light sources, a tungsten and a fluorescent, may be rated as having the same color temperature, but their effect on color film may vary considerably because of differences in their spectral distribution qualities. For the same basic reason, you can't always choose the filter that will produce proper color balance based on the filter's effect on color temperature alone. You can prove this following the manufacturer's recommendations and by making tests of your own.

TABLE 1–2

COLOR TEMPERATURES OF SOME COMMON LIGHT SOURCES

Source	°*Kelvin*
Candleflame	1850
60-watt gas-filled tungsten lamp	2800
100-watt tungsten lamp	2865
500-watt tungsten lamp	2950
500-watt projection lamp	3175
Lamps for color photography (3200)	3200
Lamps for color photography ("CP")	3350
Lamps for color photography (Photoflood Nr 1)	3450
Morning sunlight	2000–5000
White flame carbon-arc lamp	5000
Sunlight (slightly overcast)	5800
Average sunlight (1000–1500)	6000
"Daylight" fluorescent lamp	6300
Totally overcast sky	6800
Clear blue sky	12000–27000

Nevertheless, color temperature is useful as a guide in determining the corrections you need for proper color balance. You can find the color temperature of tungsten sources with two-point meters, that is, meters reading only the ratio between red and blue light. This type of color temperature meter does not adequately measure spectral energy distribution and should not be used to measure daylight. Use three-point meters for this purpose. Even then, the application of color temperature values to varying daylight conditions often tends to be misleading to the color photographer. Follow the manufacturer's recommendations and make tests whenever possible.

Daylight film. Daylight color film is balanced at 5400 K. Because of the high blue content of a light with this color temperature, the film is made with a relatively lower sensitivity in the blue record emulsion and with a higher sensitivity in the red recorder emulsion. This minimizes the excessive blue and strengthens all reds in the final transparency.

When daylight film is exposed to light with a color preponderance of red, this excess red degrades all colors, and the transparency takes on a reddish cast. Do not for a moment think that this is the only way to get reddish cast; perhaps your own experience in taking vacation pictures in color brings to mind how reddish your roll of daylight color film appeared when it was exposed under tungsten light. Essentially, you get the same effect by exposing daylight film just after sunrise or just before sunset. You have probably noticed the predominantly red light at those times, even though the eye is a poor judge of color. The opposite, or bluish cast, commonly appears in various winter snow scenes. As a matter of fact, the shadows are definitely blue in any outdoor picture, because they are illuminated by sky rather than by sunlight. Skylight is largely blue because the short wavelengths of blue light are easily scattered by atmospheric dust and haze. This, then, is the light that illuminates shadow areas.

Offcolor transparencies and prints are not necessarily poor. Take a look at the color illustrations in any photographic magazine. Many topnotch photographers deliberately use light of the wrong color temperature to shoot pictures. A reddish cast produces a warm tone, while an excess of blue is cold. Of course, these are special effects designed to create a particular mood.

You will find that daylight seldom meets the exact requirements of emulsion balance. Probably, the best check you have available is the ability of a film to produce gray as a true gray with no evident hue. If a neutral gray is reproduced as such, it can usually be taken for granted that the various colors also have been properly reproduced. One trouble with this system is its inability to foretell the proper color balance before shooting and processing. Even so, the system can prove useful to you in the laboratory when you examine processed film for color quality. If the shooting assignment is still continuing, then the laboratory should notify the photographer if color balance between the film and the illumination is not right. Within limits, you can make minor corrections in duplicating and printing the original film in the laboratory.

Tungsten film. Color materials designed for use under tungsten illumination are color balanced for illumination that measures 3200 K, 3400 K, or even 3800 K, as the case may be. The lamp that produces tungsten illumination at one of the rated Kelvin designations usually has a fixed life. This means that light of the proper color temperature is produced only when the lamp is new and within a stated time period. The time period is usually short for some lamps. For example, some lamps, known as *photofloods*, can produce light of 3400 K for only 4 to 6 hours, whereas certain kinds of 3200 K lamps have effective lives of 15 to 60 hours. Photofloods are also subject to color temperature changes caused by line voltage fluctuations. Thus, for lamps intended to be operated at 115 volts, an increase of 1 volt raises the color temperature to 10 K. Changes of less than 100 K are difficult to detect by your eye on scenes that do not have large areas of near neutrals or grays. However, on scenes with important neutral areas, your eye can detect a change as small as 50 K.

When a tungsten lamp operates for some time and approaches its rated life, there is a small shift in color temperature of its light. The shift is gradual and toward the red end of the spectrum. That is, the light becomes redder even though your eye cannot detect any change in color. Only when your eye can detect the change in the processed print do you know that a change greater than 100 K has occurred. Even then, the colors of scenes that don't have large areas of near neutrals (grays) don't appear to be seriously affected.

Most artificial or tungsten lighting is rich in red, so tungsten color films are made with a pronounced sensitivity to blue to compensate for the lack of blue. This is one reason that, when you examine a roll of processed tungsten film originally exposed in daylight, the colors seem to have an overall bluish cast. Many of the tungsten color films can be exposed in daylight if you use the right conversion filter over the camera lens, although this procedure may not be recommended by the manufacturer for some films. One reason for discouraging this practice is that the increase in exposure time may not be compatible with the available motion picture camera shutter speeds. Another and more important reason is the radical shift in color sensitivity that the film may not be able to handle. You recall that the color balance of daylight color emulsions is such that they are extremely responsive to red colors and less sensitive to blue, since daylight is rich in blue. Therefore, a color conversion filter, necessary for daylight film to be exposed under tungsten illumination (rich in red), must hold back or absorb the major portion of red light passing through the lens in order to allow light that is predominantly blue to affect the emulsion. For this reason, it is best to use color materials that are properly color balanced for the type of illumination for which they are originally developed.

When you work in the laboratory, you may never have the occasion to use conversion filters, since they are primarily used by photographers. However, you must know how they work and their effect on color emulsions, particularly since you can be called upon to examine and evaluate color films processed in your laboratory. More important, however, is the fact that you use filters in printing equipment to produce positive duplicates of valuable original film and positives from original color negatives or internegatives. In these situations, you need to know the capabilities of light-balancing filters as well color-compensating (CC) filters.

Exercises (232):

1. What happens if you expose *daylight* color film to tungsten illumination?

2. Daylight color films have a low sensitivity to what color light?

3. A daylight color film exposed to a light source of 3200 K will appear as what color?

4. Tungsten color film exposed to a correct illumination source that has been used too long will appear as what color?

5. Tungsten color film is highly sensitive to what color light?

233. Given a list describing light of different colors, name the color film layer each color exposes.

Dye Image Formation. The production of dyes is exactly what happens within the emulsion of reversal color film. Only after development does any color appear. We say more about the processing angle later, but for now it might interest you to know that reversal color film must be developed twice. The first development produces a black-and-white negative image of high contrast, and a second development produces the colored, positive image.

Refer to figure 1-46 as you follow the process of exposing and processing color film. Notice that the blocks labeled "Subject Colors" in part A include both the primary and secondary colors. Consider these blocks as though each one was a separate object so that it will be easier to follow the results from one area to another. Light is reflected from these blocks and makes an exposure on the color film in the appropriate layer. The film is then developed to a negative image, as shown in part B of figure 1-46. However, silver halides are exposed and developed only in the sensitive layer that corresponds to the color of the object. For example, a blue object exposes the top, blue-sensitive layer only. After development, the silver halides in this area are reduced to black metallic silver. Notice that the secondary colors expose two layers, black exposes none, and white exposes all layers.

After the first development, the film is exposed to white light or a chemical reversal agent to expose the remaining silver halides. The film is then placed in the color developer and appears as in part C of figure 1-46. The silver halides that were exposed during the second exposure are fully developed now. During the process of development, a strange thing happened. In addition to other chemical changes that took place, colored dyes formed. These colors are secondary colors that combine by the subtractive principle to reproduce the colors of the original subject. By following the light from our blue object, you can see that it results in the formation of magenta and cyan dyes, both of which contain blue.

The final step of the process is illustrated in part D of figure 1-46. Up to this point, you have produced a colored transparency. However, the metallic silver still remains, and it actually makes the transparency black or opaque. The next step in the process is for you to bleach out, by chemical means, all of the silver. The silver is removed, but the colored dyes remain. By allowing white light to pass through the transparency when viewing it, certain portions are filtered out (subtracted) by the dyes before the light strikes the eye. Using our original blue subject example again, notice that in the blue area white light must pass through what is effectively a magenta and a cyan filter. These two colors subtract all colors except blue. Magenta is blue and red; cyan is blue and green. Therefore, the magenta area will not transmit green, and the cyan will not transmit red. The only color common to both is blue, so it can be transmitted through both filters. The result of all this selective filter action is a reproduction of the original subject colors shown in part E of figure 1-46.

The "gimmick" that made this possible was the formation of the colored dye during the second development. The principle involved in the process is called *dye coupling*. Each color-sensitive layer of a color emulsion contains, in addition to the silver halides, a chemical that is used as a coupler, which, when it comes into contact with another ingredient in the color developer (usually an amine or analine), forms a dye of a specific color. The union (or chemical action) between color-forming chemicals takes place only while development (or silver reduction) is occuring and oxidation products are being formed. This principle of color coupling is particularly well adapted to color photography, because color is not formed in any area where light action has not taken place. Most present-day color film processes operate on this principle. Because of the similar chemical structures of the various dye couplers, the film from one manufacturer can be processed in the chemicals from another company, but any results from this intermixing will be unsatisfactory. There is color, but many odd varieties develop. Accordingly, this procedure is definitely not recommended.

There are two types of color processes in general use, protected-coupler and differential reexposure.

Protected-coupler process. The Eastman Kodak Company uses this process for Ektachrome film (and for negative color films—Vericolor and Kodacolor). In this process, each small particle of coupler is coated with resin, which holds it in place in the emulsion layer. A disadvantage is that the wet resin causes an overall

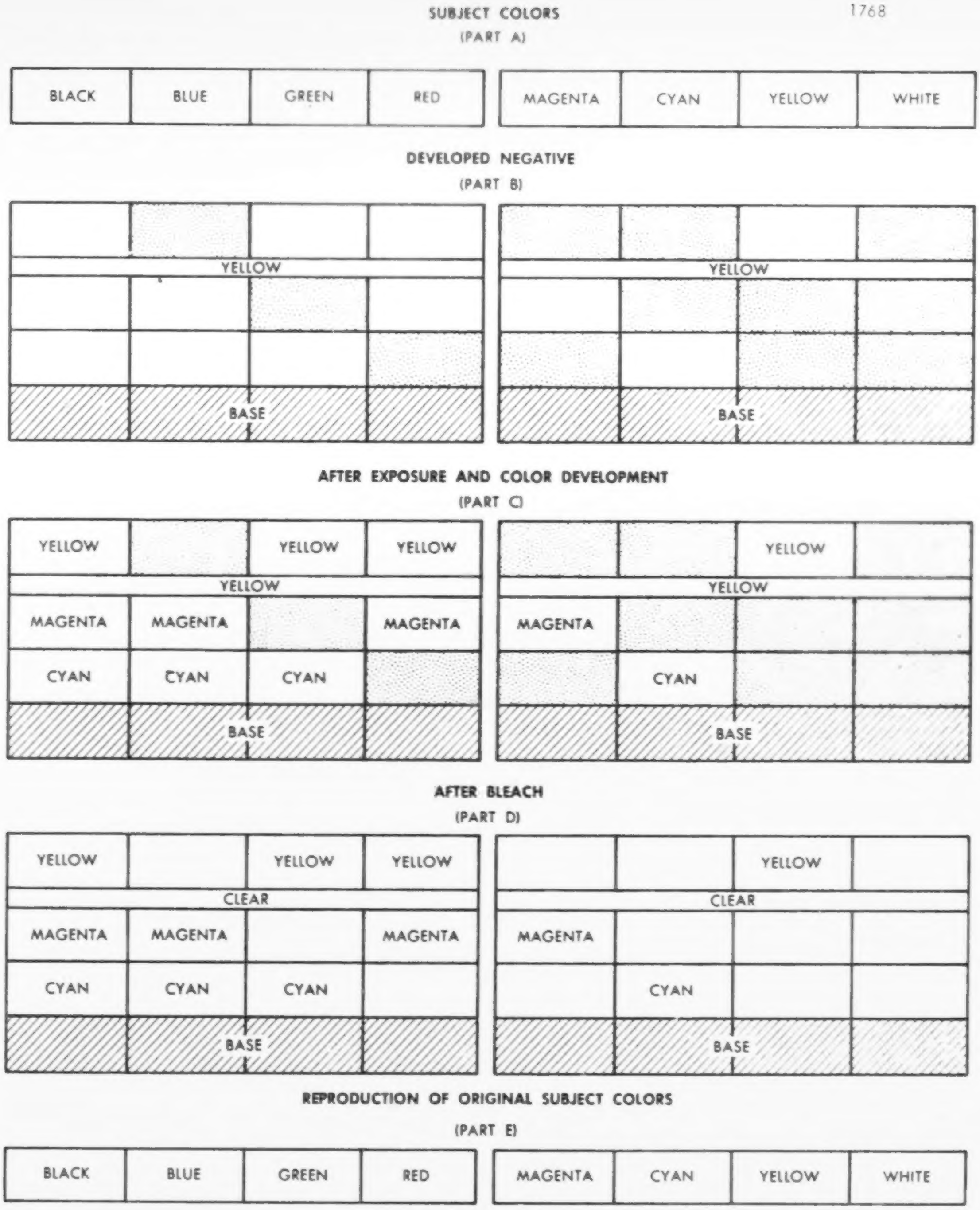

SUBJECT COLORS
(PART A)
BLACK
BLUE
GREEN
RED
MAGENTA
CYAN
YELLOW
WHITE
DEVELOPED NEGATIVE
(PART B)
YELLOW
YELLOW
BASE
BASE
AFTER EXPOSURE AND COLOR DEVELOPMENT
(PART C)
YELLOW
YELLOW
YELLOW
YELLOW
YELLOW
YELLOW
MAGENTA
MAGENTA
MAGENTA
MAGENTA
CYAN
CYAN
CYAN
CYAN
BASE
BASE
AFTER BLEACH
(PART D)
YELLOW
YELLOW
YELLOW
YELLOW
CLEAR
CLEAR
MAGENTA
MAGENTA
MAGENTA
MAGENTA
CYAN
CYAN
CYAN
CYAN
BASE
BASE
REPRODUCTION OF ORIGINAL SUBJECT COLORS
(PART E)
BLACK
BLUE
GREEN
RED
MAGENTA
CYAN
YELLOW
WHITE

Figure 1–46. Formation of the dye image.

translucent bluish appearance that makes it very hard to judge color quality until the film is dry or rinsed in a special fixer solution.

Differential reexposure process. This is the Kodachrome process. It is more involved, since it takes three separate reversal exposures and as many color developers. The necessary controls make this system hard to carry out in the average laboratory.

Exercises (233):

1. Which layers(s) of color reversal film would be exposed by each of these light colors?

   a. Red.

   b. Blue.

   c. Green.

   d. Cyan.

   e. Magenta.

   f. Yellow.

234. State what exposure characteristics indicate given variations in light intensity and color on reversal color materials.

Latitude. Unlike the panchromatic film we discussed, color materials have a much narrower range of brightness values that can be accurately reproduced. This is one reason why colors seem to be so much more vivid in color positives than black-and-white renditions of the same scene. Although color films have multilayered emulsions, their thickness is less than that of panchromatic film. The greater thickness of "pan" film serves as a cushion, because the abundant supply of silver halides increases its usable exposure range and latitude. By comparison, color emulsions are very thin, thereby considerably shortening the exposure latitude. On the other hand, thin color emulsions have an advantage in that highlights are seldom blocked up as a result of the reexposure needed for the reversal process.

Except for a few color materials, the greater portion of available color film is reversal films whose end products are seen as color film positives. The reversal process diverges from the customary steps required to produce black-and-white negatives in that bleaching, reexposure, and a second development are needed. We need these extra steps to get a positive image in each of the emulsion layers through reexposure and redevelopment. The bleach removes the silver image so that we can get a dyed image by means of various coupler agents. This substitution of a metallic silver image for one that is made up of dyes virtually eliminates grain. The reversal process, whether for color or black-and-white products, uses up almost all of the sensitive silver halides or grains to get the necessary negative and positive images. Hence, the process has an inherently low latitude of development. Thus, the reversal color process makes many demands on your knowledge of correct exposure with respect to laboratory printing of duplicates, as well as exact timing in processing color materials.

Figure 1-47 illustrates, in a general way, the influence of narrow film latitude on the reproduction of scene brightness values with reversal color material. For purposes of simplicity, consider each pair of the three views (A, B, and C) as two cross sections of color film. In each case, the upper cross sections represent the results of the film's initial exposure and its first development. Imagine that the original subject was illuminated by a predominantly red light such as you would find in a vivid sunset. Consider the shadows, halftones, as well as highlights as different densities of the same color. Normally, color material can record more shades of brightness values than figure 1-47 shows. The lower cross section represents the film after it has been reexposed and run through another development. In each view, the exposed silver halides are shown in black, while portions of the emulsions that are not affected by light remain blank.

With a normal exposure, about one-half of the silver halides (throughout the various layers of film) are affected (fig. 1-47,A). Note that the film reproduction of the subject would record the same range of brightness values as the original scene. Compare the scene results of the normal exposure with those of overexposure and underexposure. The former, shown under detail B, would appear as a very thin positive transparency, since the initial overexposure has affected the major portion of the emulsion silver halides. A considerably smaller amount of halides remains to be affected by reexposure and second development, so the result would lack the tone necessary to represent the deepest shadow area. The reduction in numbers of reexposed silver halides available for a second processing is one reason for the low latitude of development.

Underexposure of a subject (fig. 1-47,C) affects considerably less than half the silver halides in the color emulsion. Therefore when the reversal process forms the positive image, the greater part of the silver halides are affected by reexposure and the second development. As you might surmise, this second development produces a positive silver image (and resulting dye image) that is proportionately heavier than the negative image (resulting from the initial underexposure). That is why an initial underexposure (whether in the camera or in printing equipment) produces a dense, color-saturated positive.

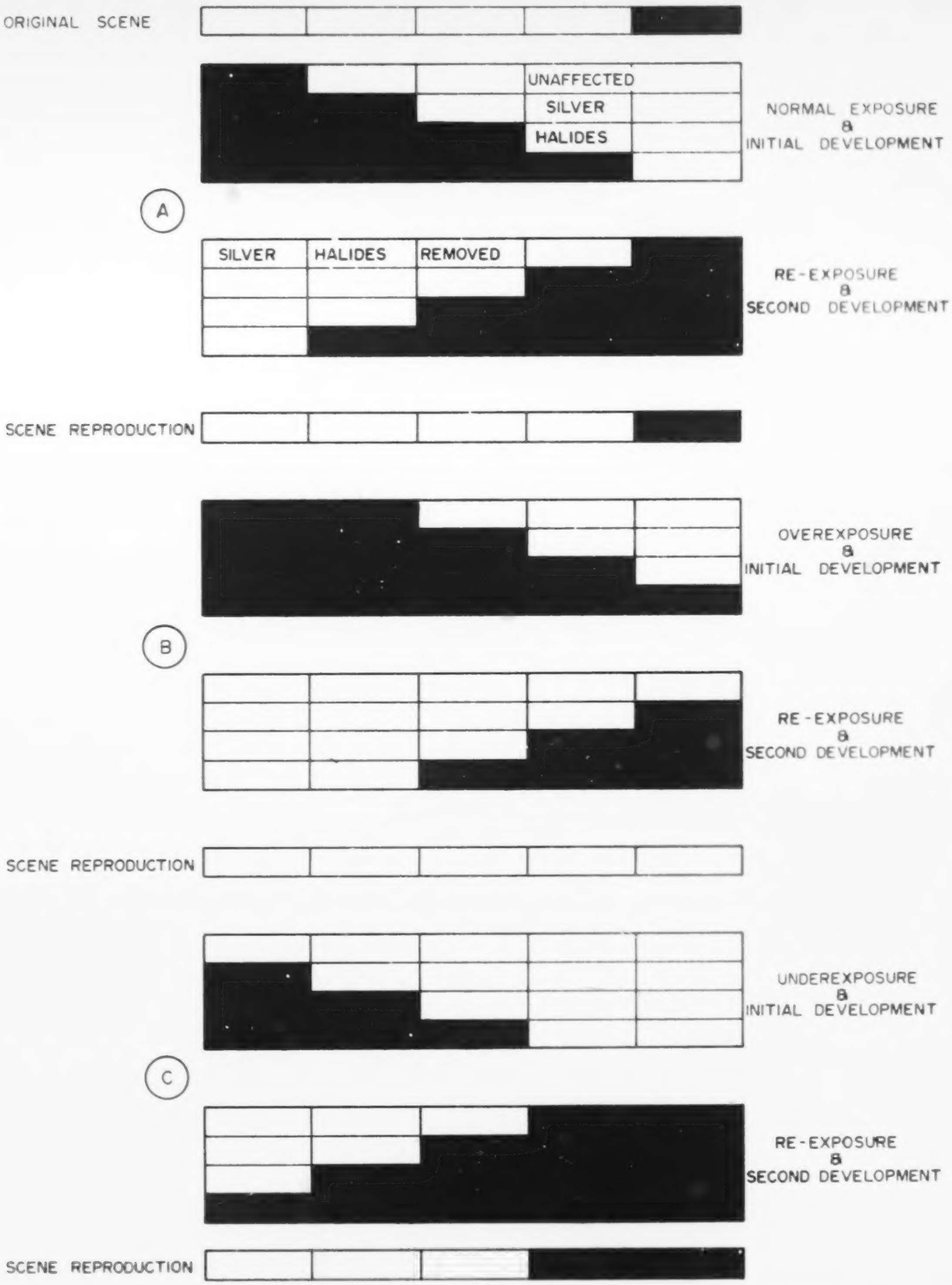

ORIGINAL SCENE
UNAFFECTED
SILVER
HALIDES
NORMAL EXPOSURE & INITIAL DEVELOPMENT
A
SILVER
HALIDES
REMOVED
RE-EXPOSURE & SECOND DEVELOPMENT
SCENE REPRODUCTION
OVEREXPOSURE & INITIAL DEVELOPMENT
B
RE-EXPOSURE & SECOND DEVELOPMENT
SCENE REPRODUCTION
UNDEREXPOSURE & INITIAL DEVELOPMENT
C
RE-EXPOSURE & SECOND DEVELOPMENT
SCENE REPRODUCTION

Figure 1-47. Film latitude.

Exercises (234):

1. If the first exposure of color reversal film exposes only one-third of the silver halides, would the final transparency contain too much density, or too little density?

2. State in which color the exposing light was deficient to produce these excess dyes:

   a. Cyan.

   b. Yellow.

   c. Magenta.

3. What causes a thin transparency?

235. Distinguish among the physiological properties of color as they relate to color material contrast.

Contrast. Contrast is a measure of the difference between the greatest and the least density recorded on photographic material, regardless of whether these two densities represent the straight-line portion of the D log ~~E~~H curve or not. Sometimes contrast is called gamma, which represents the straight-line portion of the curve between two specified points. Since most photographic personnel think that they are working only along the straight portion, the terms "contrast" and "gamma" are often used interchangeably.

Another way of expressing contrast is by the fidelity to which variations in subject brightness are reproduced as various densities comprising the photographic image. Contrast in color materials requires you to draw up (or plot) three characteristic curves—one for each of the dye images. This is an important requirement in making separation negatives, since you must process each to the same degree of contrast. Multilayer color materials, on the other hand, are designed so that the desired gamma is produced for the three images with a single development time. The reason for this seemingly odd deviation is that multilayer emulsions, using the subtractive process, may safely use a low-contrast blue record with a high-contrast yellow record and still produce a positive that has the proper contrast for ideal color and tone reproduction.

Before we can understand just why the proper contrast for color material is important, let's define color, list its essential properties, and find out why we see color. Recall that color is a sensation that light creates by stimulating certain substances in the retinal portion of your eye. The stimuli are transmitted to the brain, where they are interpreted as color. Although sensations are difficult to measure, we can say that color has certain physiological properties: *hue*, *value*, and *chroma*.

Colors, themselves, can be divided into two broad groups: those that have hue are known as chromatic colors, and those without hue (such as black, gray, and white) are known as achromatic colors. Hue, therefore, distinguishes colors from blacks, whites, and grays. Hue also lets you distinguish between two colors, that is, to recognize red from green or blue from yellow.

Value is a property that relates colors to tones or shades of gray, which range from white to black. In viewing a green meadow under various lighting conditions, although the grass may appear much darker in the deep shadow under a tree, you recognize the color as green. The eye recognizes the green coloring of grass as continuous whether in deep shadow, under the hazy shadow of a cloud, or in brilliant sunshine. Thus, the green of grass in the meadow may range from light to dark. The same situation occurs when you view other colored objects about you—for example, a red brick building or leaves of a tree.

The remaining property is known as chroma, and it relates to the purity (or situation) of a color. Chroma allows you to distinguish a color having hue from a gray tone of the same brightness. Another way of defining chroma is the extent that a color deviates from the achromatic and approaches a pure hue. Disregarding its intensity, the sun can serve to show chroma of a limited degree. High overhead at noon, the sun appears as a white-hot disk with such brilliance and intensity that it is extremely difficult to observe the sun with the naked eye. However, as the sun nears the horizon, its color gradually changes from white to red, with the red becoming more pure as the sun sets.

It is normal practice to develop many kinds of color material that incorporate the subtractive color process to the point where slightly higher than normal contrast is to be obtained. One reason for increasing the contrast is to get more saturation of the colors used to produce the colors of the original subject. Because of the excellent control over the color process in the laboratory, increased contrast of duplicating material in the printing section is compulsory when low-contrast film originals are being reproduced. The danger appears when the contrast of one image becomes excessive while the contrast of the remaining dye images may be normal. The resulting print will have one of the primary colors appearing close to its original hue with an exaggerated value and chroma, while the remaining primary colors lack hue, value, and chroma. The result is often seen in color prints in which the blue sky appears natural, but red brick buildings and the lawns around them appear unnatural. By changing the lamp voltage or by using color filters, duplicates made from such originals can, within limits, be printed with natural appearing colors for the brick and grass. Experience has shown that it is better to produce prints with colors that have consistent differences. In such prints, even though the colors may be off, the tones (brightness) of each color are separate and distinguishable, just as they were in the original subject.

Exercises (235):

1. What enables you to distinguish a tank from its camouflaged surroundings in an aerial photograph?

2. What physiological property is tied most closely to overexposure and underexposure?

3. What property relates colors to tones or shades of gray?

236. List recommended environmental conditions for storing color materials.

Care of Color Materials. Much of our discussion about the care, storage, and handling of black-and-white materials applies equally well to color materials. As you probably know from your experience in buying color film, the cost of color materials and processing (if it is not included in the original film cost) is almost three times the cost of black-and-white film materials and processing. You can appreciate that the Air Force has a substantial overall investment in processed color materials when you consider the expenses involved for raw stock, studio production (special color-balance illumination, etc.), processing, and printing. While this is especially true of camera film originals, you must give equal consideration to color internegatives, color duplicate negatives, and in some cases, to release prints.

Color materials with their thinner emulsion and dye images require a somewhat special kind of care to preserve the natural colors recorded in the film. Therefore, in addition to maintaining ideal storage facilities, environmental conditions must be rigidly controlled to avoid damaging multilayer color emulsions, film base, or the dyes that make up the colored image.

It is extremely important that you avoid any changes in either the length or the width of color materials (or hold them to a minimum), since individual dye images must be in perfect register for proper printing operations. As a rule, by maintaining control over the relative humidity (RH) content and temperature of properly constructed film storage area, you can protect color materials from environments that cause these changes. As in the case with black-and-white films, keep the relative humidity (RH) of the storage facility for color materials at 40 to 50 percent. However, processed color negatives and prints are readily subject to changes. To prevent fungus growth as well as to minimize fading of the colored dyes, you must not exceed the 50 percent RH figure. Several changes in dye colors can also result if you do not use a stabilizer solution in processing certain types of color film.

Exercises (236):

1. What environmental conditions must one control for the proper storage of color materials?

2. What relative humidity is ideal for storing unprocessed color materials?

237. State the effect of given color material storage problems.

Effects of Improper Storage. Bear in mind that shrinkage due to film aging is a permanent change in its size. Such shrinkage can be hastened by storing film under high relative humidity conditions. The presence of moisture helps to diffuse the residual solvents within the film base. Other causes of permanent changes include the loss of plasticizer and, to a lesser extent, the gradual elimination of strains introduced during film manufacture and processing of exposed film. Storage under high temperature also speeds up the rate of film shrinkage.

Color materials require lowered temperatures as well as controlled humidity conditions to preserve the high initial film speed (particularly of negative raw stock) and to maintain the color balance and sensitivity. However, for a printing section, it is much more important to maintain high uniformity from roll to roll than it is to preserve initial film speed. This uniformity is best attained by having a constant temperature that is evenly distributed throughout the storage facility. The temperature need not be especially low. To assure high quality, sealed containers of most kinds of color film can be stored safely for 6 months at of 50°F. before their use. Color materials, such as Kodachrome and Ektachrome, however, can be stored at a temperature somewhat higher—65°F. Temperatures lower than 50°F. can be used for film storage with no adverse effects, but don't forget to let them warm up before you use them, or they'll develop moisture condensation, especially when there's a difference of 25° between storage and outside temperatures. For periods longer than 6 months or for archival film storage, it is customary to store color materials at 0°F.

Processed color materials that are to be stored are treated differently from raw stock. Before processed color film can be stored, it is essential that you throughly wash all residual chemicals from the development, bleach, and fixing baths. Make a mercuric chloride-potassium bromide test to check the hypo or thiosulfate salt content of the film you're going to store. If the level of hypo is high, it may be quicker to duplicate the film and take particular care in washing to remove residual chemicals. The salts in hypo can cause the dyes in the image to fade. Unfortunately, the fading is uneven, since one dye can lose more color than another. Unused dye couples remaining in the film must be treated chemically to prevent color changes and to bring the emulsion layers to their proper pH value. The maximum amount of hypo (as anhdrous sodium thiosulfate) that can remain in color film should be no more than 0.002 to 0.003 milligram per square inch.

Because the dye images of color materials are extremely sensitive, you must guard against contamination of all kinds, particularly to see that the atmosphere within storage areas does not contain acid vapors or gases (as sulfur dioxide or hydrogen sulfide) that could damage the dye image. Other factors that can cause the dye image to change color or fade are heat, light, and moisture. As a rule, the stability of a dyed image increases when the storage temperature is lowered, and the relative humidity is decreased. As with all things, there is a limit to temperature and humidity reductions. Experience has shown that no additional image stability is to be gained by providing storage temperatures below 55°F. or relative humidities of less than 40 percent. As is the case with panchromatic films, very low percentages of relative humidity induce color material to become brittle.

In both commercial and military laboratories, great concern is expressed over the protection given to camera originals whether they are color negative or color reversal materials. Not only are storage environments carefully controlled whenever possible, but also the length of time such originals are stored is limited in facilities whose atmosphere cannot be adquately controlled. For example, in storage facilities where moderate conditions of 70°F. and 50 percent RH are present, you can expect some fading of the dye image. Of what importance is this? Although some fading and small image density changes are present, the printing laboratory can still produce acceptable prints from such originals by making minor changes in the printer exposure time and printer lamp color temperature.

Ideally, it would be better to separate original color negatives and color duplicate negatives and store them separately. You should be aware that the chemical structures of the dyes that are used in various kinds of color material are not necessarily the same, just as the processing times for various films are not the same. Therefore, the rate and amount of fading of the dye images of original negatives are seldom the same as those of duplicate negatives. Storage facilities should be inspected at established intervals to see whether the recommended temperature and RH conditions, as well as the physical well-being of the film, are being maintained. Under no circumstances should the interval between inspections exceed 2 years. Where voluminous film files are kept under controlled atmospheric conditions, random film containers should be opened and the film examined to check for damage caused by heat, humidity, and fungus.

Exercises (237):

1. Color material that has been stored for several months shows advanced deterioration of the dye images. What could cause this?

2. What damage is likely when the relative humidity of a storage facility exceeds 50 percent?

3. Your laboratory receives a large supply of color reversal camera film. Laboratory technicians decide to store all of it at 50°F. What effects can be expected if all of this film is not used within 6 months?

1-7. Composition of Black-and-White Solutions

When a photographic emulsion is properly exposed to light in a camera or on a printer, an invisible change is produced in the minute crystals of silver halides. This change forms the latent image. To obtain a visible image, the exposed emulsion has to be treated in a solution known as a developer. This solution converts the light-affected halides to black metallic silver. These black metallic silver particles form the visible image.

There are many theories as to the exact nature of the change or reaction that takes place when a light-sensitive material is exposed to light, but for our purposes it is enough to know that the light affects the halides so that we can reduce them to a metallic silver with a chemical known as a reducing agent. In photography, a reducing agent is commonly referred to as a developing agent.

Although many chemicals can reduce silver halides to metallic silver, relatively few of them can be used as developing agents. To be a useful developing agent, a reducing substance must be able to distinguish between exposed and unexposed silver halides. In other words, it must develop only those silver halide crystals which have been exposed to light.

238. List the five components of a conventional developer and distinguish among their functions.

Developer Solution Chemicals. For a photographic developing solution to be effective, it must contain more than just the developing agent. It must contain water in which everything else is dissolved. It must also contain a preservative, an accelerator to make the developing agent function, and a restrainer to keep the developing agent from "running away." Now, let us examine the various components of a developing solution in more detail, starting with the solvent.

Solvent. Water is used as the solvent for mixing the chemical components of a developing solution. Without water, the dry chemicals couldn't soften the emulsion to let the chemicals penetrate so that the necessary technical reaction can take place. Distilled water is often used as the solvent, but it is not superior enough to ordinary tap water to justify its extra cost. Water in most water supply systems is normally a perfectly satisfactory solvent.

If you doubt the purity of your water supply, use distilled water. Distilled water is "pure" water, but it gets rather expensive in the large quantities necessary for photography. Boiled water is an adequate substitute for distilled water. Boiling causes may of the impurities in water to turn into insoluble substances. When the impurities settle, the clear water can be poured off. Boiling also eliminates dissolved gases and air from the water. Unless the water contains excessive quantities of dissolved salts, boiling usually affords enough purification for photographic purposes.

Filtration is often used to remove suspended or undissolved matter from the water. In small quantities, water may be filtered through a fine mesh cloth fitted into a funnel. Purification of water for photographic use may sometimes require a combination of both boiling and filtration. Remember, however, that most tap water is pure enough for photographic use. Boiling and filtration are necessary only in extreme cases. Usually, if the water is fit to drink, you can use it in photography.

Developing agents. Many different substances have been used as photographic developing or reducing agents. A property common to all reducing agents being used today is the ability to tell the difference (discriminate) between exposed and unexposed silver salts. Without this selective quality, the reducing agent would also attack the *unexposed* silver salts, turning the entire emulsion a uniform gray or black. As a result, no distinct subject image would be formed.

In addition to the way they discriminate between exposed and unexposed silver salts, reducing agents have many other highly variable characteristics. Of these, one of the most important is the *reducing potential*. Reducing potential refers to the developing agent's relative ability to develop, or reduce the silver halides to metallic silver. A reducing agent of high potential attacks silver halides vigorously, whereas one of low potential is slower in its actions. Another characteristic of a reducing agent is how it acts with respect to the "strength" of the latent image. Some developing agents are more active in the highlight areas of the emulsion, some in the shadow areas, and still others have an overall activity.

Among the other characteristics of developing agents, some require more consideration than others, depending on the developer's use. The temperature of the solution affects the activity of some agents much more than others. The tone of the final developed image is greatly affected by the type of reducing agent. Some agents produce blue-black (cold) tones, while others yield brownish (warm) tones. Now, let's put a name to two of the most common developing agents. These are names with which you will become increasingly familiar as you gain experience in photography.

One outstanding developing agent is called *hydroquinone*. This is a developing agent of low potential. It is a slow-acting, but powerful, low-energy reducing agent. Its activity is greatly reduced by low temperatures because it becomes inert (inactive) at about 50°F. in normal solutions. Above 80°F., it has a tendency to produce fog on the negative (it starts reducing unexposed silver halides). Hydroquinone can produce highlights of great density in a negative while retaining transparency in the unexposed areas. This makes it an ideal developing agent for subjects requiring extreme contrast; for example, copies of black-and-white line drawings. For subjects that require the correct rendering of middle tones and shadows, it is combined with another reducing agent, called Metol. Hydroquinone deteriorates slowly in air, has good keeping qualities in solution, and does not stain the gelatin emulsion.

Metol (Elon, Pictol, Rhodol, etc.) is a trade name for a chemical that is quite a mouthful to pronounce. This chemical is known as monomethyl paraminophenol sulfate (you can see why they shortened the name). Metol alone, or combined with hydroquinone, has been one of the most popular of all developing agents since its introduction in 1891. It builds image detail rapidly and is a soft-working high-potential developing agent affected comparatively little by changes in temperature or by the presence of large amounts of restrainer. Metol is often used in fine-grain negative developers, although it has a tendency to stain hands and fingernails, it does not stain the gelatin of the emulsion. It has good keeping qualities and can develop a larger amount of sensitized material before becoming exhausted than any other agent.

Preservative. A preservative of some kind is necessary to prolong the life of the developing solution. Reducing agents keep very well in an acid state, but most of them will not reduce (develop) the exposed silver halides unless the solution is alkaline. As soon as you make the solution alkaline by adding other chemicals, the reducing agents readily absorb the free oxygen from the solution, become oxidized, and generally turn brown in color. The solution then loses its developing strength (reducing potential), and any sensitized materials placed in the solution will be stained. If something is not added to the developer to prevent oxidation, the oxidation will continue until the developing agent loses all its strength. A chemical is needed to prevent this oxidation and keep the solution clear. Thus, we have the purpose of the preservative in the developing solution.

The most common preservative is sodium sulfite, which is effective and inexpensive. It absorbs the free oxygen from the solution *before* the oxygen can combine with the reducing agent. This happens because sodium sulfite has a greater need to combine with oxygen than does the developing agent. Since it is the first to combine with any available oxygen, it delays the oxidation of the developing agent. With the protection, the solution stays colorless for a longer period of time or until its energy is used up in processing photographic emulsions.

Accelerator. All developing agents are either neutral or slightly acid, so they usually have very little reducing (developing) ability. For us to use their reducing capability, they must be in an alkaline state. Therefore, we add an accelerator to the developing solution to make it alkaline. The accelerator energizes the reducing agent and softens the emulsion, permitting more rapid penetration of the developing solution.

The action of an accelerator is very similar to washing your hands with soap. The soap lowers the surface tension of the water and opens the pores of your hands, letting the water penetrate and wash out the dirt. In the same way, the alkali opens the pores of the gelatin, letting the solution penetrate down to the embedded silver halide crystals and reduce the exposed ones to metallic silver. The alkali also allows many by-products of development to be washed out of the emulsion as the exposed silver halides are being reduced. Too little alkali retards development. Too much causes an increase in activity and contrast on the final negative, chemical fog, and an overswelling of the gelatin, which may form blisters or peel the emulsion away from the base. As you can readily see, the kind of accelerator and the quality used in the formula are extremely important for the proper balance and stability of the developing solution.

Depending on the purpose of the developer, the solution may contain one of three general types of accelerators: mild, moderate, or strong alkalies. The mild alkalies are used with low-contrast developers to produce fine-grain results. Borax, one of the mild alkalies, is used extensively. Another alkali of this same classification has the trade name "Kodalk." Most developer formulas call for sodium carbonate as the accelerator. This chemical is fairly inexpensive and has good stability throughout the life of the developer. It is termed a moderate alkali, and is widely used in "average" developers.

The third type of accelerator is the strong one. Accelerators of this type are usually sodium hydroxide (often called lye or caustic soda) and potassium hydroxide. These are caustic alkalies used with certain developers to produce high contrast. Because of their strong chemical action, alkalies of this type must be handled with extreme care. A developer formula containing a caustic alkali as an accelerator is usually very vigorous and is used in copying line drawings and charts. It is usually used in solutions with a slow-working high-contrast developing agent, such as hydroquinone, which produces very little fog. The stability of this type of formula is very low, so it has to be used within 2 or 3 hours after mixing, and it is discarded after use. Caustic alkalies are not used for fine-grain developers because they soften and swell the gelatin excessively, letting the silver grains clump together.

Restrainer. We previously mentioned that an accelerator is added to speed up the developing agent's action. This effect is much like the effect produced by the accelerator on an automobile. Press the gas pedal to the floor and the car speeds up. The car goes faster and faster until eventually it goes out of control—as does the developing solution unless we apply a brake to the action. In a developing solution we add a restrainer to act as a brake so that the developing agent-accelerator combination does not run away and cause the development of unexposed halides (fog).

Without a restrainer, most developers act too rapidly and reduce unexposed silver halides near the surface of the emulsion, causing chemical fog, developing streaks, and creating an image lacking in contrast. When a restrainer is added to the developer, development time is somewhat prolonged and fog is minimized. If too much restrainer is added to a formula, the time of development must be lengthened so much that fog will be produced in spite of the restrainer. Under some conditions, excessive restrainer will cause a greenish tone, which is especially noticeable on prints.

Potassium bromide is the chemical most commonly used as a restrainer. Negative and some paper emulsions are basically composed of silver bromides. During development, the bromide is released from the silver. Although this bromide acts as a restrainer to a degree, it is usually insufficient by itself to prevent fog. Therefore, more potassium bromide is necessary.

A restrainer is not always required in a developing solution. Many fine-grain negative developers that are weakly alkaline don't include a restainer, because their accelerator is weak (our car cannot go too fast in the first place since it has a low-horsepower engine) and their preservative content is high. In this case, the preservative (in large quantities) acts as a mild solvent of the silver halides. As the silver is being reduced during development, bromides or other salt by-products are being formed. These by-products furnish enough restraining action in a weak alkaline solution to eliminate the need for more restrainer.

Exercises (238):

1. List the five components common to most conventional developers.

2. Which developer component is responsible for each of these functions?

   a. To combine with the oxygen of the air and prevent staining of the emulsion.

   b. To slow the rate of development.

   c. To serve as the carrier of all chemicals.

   d. To assure penetration of the reducing agent into the emulsion.

   e. To change the silver halides to metallic silver.

239. State the purpose and types of stop baths, and state the probable cause of chemical defects that might be found in processed film or processing solutions.

Stop Baths. A stop bath (acid rinse) is needed for three main reasons:

(1) To interrupt development instantly by neutralizing the alkali of the developer that is trapped within the film or sensitized paper. Since the developing agents in the standard formulas don't function in an acid state, the developer left in the emulsion stops developing when an acid stop bath is used. This stopping of development is very desirable when you need controlled processing time.

(2) To prolong the life of the fixing bath. Without a stop bath, the acid of the fixing bath is used up in neutralizing the alkali of the developer carried over to the fixing bath.

(3) To keep the fixing bath from staining photographic prints. Staining might occur if the sensitized paper were transferred directly from the developer to the fixing bath without proper agitation in the fixing bath.

When you remove a negative or print from the developing solution, the emulsion is soft and swollen. Also, a small amount of developer remains both on the surface and in the emulsion. If you don't remove the developer, it continues its reaction and causes staining. Therefore, to remove the surplus developer and to stop the reduction process, place the negative or print in a stop rinse bath.

There are three general types of stop bath: *water, acid,* and *hardening*. Each has a specific purpose and should be used accordingly. Water helps to retard development and to remove excessive developer from the emulsion. Thus the use of water prevents contamination of the fixing bath. Also, although water does not neutralize the alkali in the developer, it dilutes the alkali and greatly diminishes further development. Water is suitable for both negatives and prints, and it's sometimes used before the acid stop bath in print processing.

In contrast to water, an acid stop bath stops all development by neutralizing the action of the developer. Consequently, this bath prolongs the life of the fixing bath. A good stop bath should be mild in its acid content to prevent blisters or pinholes on the photographic material, and yet it should stay acid during a normal processing or printing session. A concentration of from 0.5 percent to 1.25 percent of acid is recommended for most work. Acetic acid is one of the most satisfactory stop bath acids. In most cases, use a weak solution (approximately 1 percent) of acetic acid. Other acids, such as sulfuric acid or nitric acid, are too vigorous in their action and neutralize too rapidly (in a 1 percent concentration) for most photographic work.

Once again, a word of caution: You may think that if a little acetic acid will do the job, a lot of acetic acid will do the job better. If you do, you are wrong] Short stop baths stronger in acid content than 1.25 percent can cause blisters or pinholes. These effects are caused by the rapid formation of carbon dioxide bubbles during the neutralization of the alkali carried over with the sensitized material. Be sure to agitate photographic material when you first place it in the stop bath. This helps to prevent blisters, pinholes, and stains.

A hardening stop bath (chrome alum) is used to harden the emulsion in high-temperature and tropical processing. If you work in a photographic laboratory where you can't keep the temperatures of your solutions below 75°F., then you should use a hardening stop bath.

Fixing-Bath Chemicals. When the film has been developed and the alkaline developer neutralized to a degree with a rinse bath, there are still some exposed, undeveloped halides left in the emulsion. These undeveloped silver halides are sensitive to light, and if they are left in the emulsion, they eventually darken, making the negative unusable. You remove these halides by changing them to a soluable state in a solution called a fixing bath. Most fixing baths contain more than one chemical agent. The chemicals most commonly used in a fixing bath are silver halide solvent, neutralizer, preservative, hardener, and buffer.

Silver halide solvent. In addition to water as a solvent for the various chemicals, the fixing bath must include a silver halide solvent. This is also known as a fixer, or fixing agent. The most commonly used fixer is sodium thiosulfate, also known as *hypo*. The sodium thiosulfate changes the silver halides to a compound that is soluble in water. A fixing bath composed of just sodium thiosulfate and water may be used to remove the undeveloped silver halides, but other factors require the addition of other chemical agents. A solution of hypo and water would remain effective for only a short time since it would soon become contaminated with various chemicals carried over from the developing solution. In a short time, negatives or prints would stain and fix incompletely, or not at all. To help prevent this from happening, three or four more components are normally added to the fixing bath.

Neutralizer (acid). Do you remember how we added an accelerator to our developing solution to speed it up? After development, the pores of the thickened emulsion retain a considerable amount of developer that's still in an alkaline state. If left there, the developer continues its activity. Even though the emulsion is thoroughly rinsed before it is placed in the fixing bath, enough of the developer remains in the emulsion to continue this activity, causing the emulsion to become stained and unfit for use. To stop development and prevent staining, acetic acid (like the acid in vinegar) is added to the fixing bath. The acid neutralizes the alkalinity of the developer. As soon as the developer remaining in the emulsion is neutralized, it stops working.

Changing the developed emulsion from an alkaline to a neutral state has solved one of our problems, but it has caused another. Adding acetic acid to the hypo solution turns the fixing bath milky and renders it useless by decomposing the hypo, so we must add a preservative to prevent the decomposition.

Preservative. When a enough acid is added to the fixing bath to neutralize the alkalinity of any remaining developer, the hypo (sodium thiosulfate) is decomposed into free sulfur and sulphurous acid. To prevent this, we add sodium sulfite, which acts as a preservative by combining with the sulfur and forming new sodium thiosulfate. Sodium sulfite not only keeps the acid from decomposing the sodium thiosulfate, but it also prevents discoloration of the solution and helps eliminate stains. You remember that this same chemical is used as a preservative in developing solutions. By now, you should realize that sodium sulfite is a handy chemical to have around your photographic laboratory.

Hardener. Do you remember that we said the gelatin emulsion softens and swells during development? Because it is soft and swollen, it is also subject to damage (scratches, abrasions, fingernail digs, etc.) If processing is continued without hardening the emulsion, the negative is easily damaged. The most common hardening method is to add the hardening agent to the fixing bath. This allows the emulsion to be simultaneously fixed and hardened. You save time by fixing and hardening the emulsion at the same time. The most common hardening agent used in a fixing bath is *potassium alum*.

Buffer. One more chemical, boric acid, is sometimes added to fixing baths to retard the formation of aluminum sulfite sludge and to prolong the useful life of the fixing bath. Used this way, boric acid is called a buffer, and it lets you make maximum use of the fixing bath before it must be discarded.

Exhausted Fixing Baths. Some of the characteristics that determine exhaustion of fixing baths are milky appearance and sulfurous odor (both occur when the buffer is insufficient), a slippery feel to your fingers (insufficient quantity of neutralizer), and bubbles that don't disappear. A fresh fixing bath has a distinct pungent odor of acetic acid and has a grippy feeling to your fingers. The large bubbles that form in an exhausted fixing bath during agitation do not disappear readily—bubbles in a fresh bath do.

Exercises (239):

1. Briefly state three reasons for preparing a stop bath.

2. Name the general types of stop bath.

3. Fixer that quickly discolors, causing stains in the emulsion, is probably missing which component?

4. When a fixer solution gives off a slight sulfurous odor, what component is probably missing?

5. What is the fixer component that renders the unexposed silver halides undevelopable?

6. If scratches are produced on negatives by friction with the bottom of the fixer tray, what fixer component is probably missing?

7. What's the probable cause of blisters or pinholes on negatives?

1-8. Composition of Color Solutions

Color films are normally processed with premixed chemical provided by the manufacturer and specially formulated for each particular type of film. Careful attention to the manufacturer's instructions usually assures optimum results. However, films may yield poor or unacceptable imagery due to a variety of reasons such as improper processing procedures, incorrectly mixed chemicals, or inadequate mineral content of the processing wash water.

240. List the different solutions for a typical reversal color process and state the number of washes the process requires.

Reversal Color Processing. The final step in the production of an image is processing. There are numerous color photographic processes; some of these produce a negative image, while others produce a positive transparency. Some of these processes include the Kodak EA-5 process for aerial color films, the E-6 and C-41 processes for still photocolor processing, and the ME-4 process for motion picture processing. The following information is based on the 1811 Ektachrome RT Processor utilizing its EA-5 chemistry. The processing solutions for the EA-5 process are:

(1) Prehardener.
(2) Neutralizer.
(3) First developer.
(4) First stop bath.
(5) Wash.
(6) Color developer.
(7) Second stop bath.
(8) Wash.
(9) Bleach.
(10) Fix.
(11) Final wash.
(12) Stabilizer (not in the EA-4 process).
(13) Dry.

These processing solutions use working solutions as replenisher, except for the first developer, and color developer which have separate replenisher formulas.

Exercises (240):

1. List the different processing solutions for EA-5 chemistry.

2. How many different washes are used in the EA-5 process?

241. State the purpose of each reversal color processing solution, and state the relationship of each solution to the reversal color process.

Functions of Color Solutions. The following material describes the composition, function, and variables of each step of reversal color processing in more detail.

Prehardener. Color emulsions are relatively softer and more susceptible to abrasion, edge skiving, and scratching than are black-and-white emulsions. Photographic emulsions are basically coatings of gelatin on a support material, and gelatin becomes soft and expands in water (especially at high temperatures). This creates a problem of scratching and abrading the emulsion. The prehardening solution reduces emulsion swelling and makes the emulsion resistant to physical damage during processing.

Unhardened emulsions, if exposed to the high temperatures of process solutions, would get soft enough to leave the support material.

The prehardener step is a critical one for several reasons, in terms of the prehardener's chemical composition and the time and temperature of the prehardening. The amount of prehardening a film receives affects the rate at which subsequent solutions will diffuse into the emulsion. This hardening depends on the temperature and duration of the prehardener step. Changes in the concentration of the solution will also affect the amount of hardening, so the chemical composition must be carefully controlled.

The primary variable at this step is the degree to which the film is hardened. The development of the various layers depends on the rate at which the chemical ingredients of the developer diffuse throughout the emulsion. This diffusion rate depends on the hardness of the emulsion. The less hard (thus, more swollen) the emulsion, the easier it is for the developing agents to penetrate. Hardness depends on a number of process variables, the more important of which are:

a. Temperature—Increased temperatures increase hardening. An increase in temperature results in a color shift to greenish cyan, while a decrease shifts the color to a reddish magenta appearance.

b. Time—Increased time increases the degree of hardening. Too little time in the prehardener causes a loss in density.

c. Sulfate concentration—Increasing or decreasing the sodium sulfate causes increased or decreased hardening, respectively.

d. Antifoggant No. 6 concentration—Varying the concentration of this agent significantly affects the rate at which development is initiated in the three layers. A concentration increase slows the yellow dye layer and decreases the density created during first development (shown as a density increase in the reversal process). The density of the magenta and cyan dye layers moves in the same direction as the yellow, but there is proportionally less change.

Neutralizer. Coated as an integral part of each layer of a tripack, incorporated coupling agents (or couplers) eventually react in the color developer to form the colored dye image. They also react with the aldehydes used to harden the gelatin (if the two are brought together in an alkaline solution), forming colorless compounds. While these compounds do not degrade the image, their formation depletes the amount of couples remaining in each layer, thus decreasing the quantity of dye that can be formed. This aldehyde-coupler reaction cannot take place in acidic solutions such as the prehardener or neutralizer, but it would occur if aldehydes were carried over into the first developer (a solution which is quite alkaline in nature). The purpose of the neutralizer is to form harmless complexes with any aldehydes carried over from the prehardener so that they cannot react with couples when the emulsion enters the alkaline first developer solution.

The neutralizer step is one of the less critical in the overall process. Temperature, time, and concentration of the major ingredients control the rate at which the neutralizing agent reacts with the free aldehydes. It is, however, a completion reaction, which proceeds quickly until all aldehydes are completed. Since hydroxylamine sulfate acts as a development accelerator that may produce chemical fog (a decrease in maximum density in reversal processes), extended periods of neutralization would probably be sensitometrically detectable.

However, if the hardening agents are carried over into the first developer, they cause a significant density loss and a color shift toward bluegreen. Neutralizer cannot be overreplenished, and the mix keeps in storage up to 4 months.

First developer. The most critical step in the entire process, the first developer, may be thought of as a modified black-and-white developer. Its purpose is to form a negative black-and-white image in all three layers of the color film. It is at this point in the process that speed and contrast of each layer is determined. While black-and-white processors vary the sensitometric characteristics of a film by altering transport speed or path length, these changes are made in the color Versamat by varying the temperature of the first developer. The many critical chemical components of this solution require that replenishment rates be accurately determined and controlled to keep concentrations at optimum levels. Time of processing and the temperature of the solution are extremely important. The top, or blue-sensitive, layer forms a silver image in areas where blue light was present during exposure. There is no image formed in areas where there was no blue light. The middle, or green-sensitive, layer forms a silver image where green light was present. The bottom, or red-sensitive, layer forms an image where red light was present. Each layer is sensitive to one of the additive primary colors. At this point in the process, the image would look much like a black-and-white negative.

As the most critical step in the process, the first developer is subject to a large number of variables, all of which affect the final product to some degree. The use of packaged chemicals minimizes the number of chemical variables that may affect the process. Temperature and replenishment rate are the two most significant factors. *Manufacturer-recommended replenishment rates are compounded for average imagery and must be increased or decreased to compensate for overexposed or underexposed film*. Hydroquinone and bromide concentrations appear to give the best indication of replenishment correctness. The first developer primarily controls the relative speed; that is, the density of the final transparency depends on the amount of development received in the first developer. An increase in either developing time or temperature will decrease the densities of all colors by approximately equal value. An increase in pH decreases the contrast. A decrease in any of the others causes the reverse effect. With most films, you can change effective film speed by changing either the first developer temperature or processing time. An increase of about 5°F. to 7°F. increases the effective film speed one f/stop. You can also get a one-stop increase by increasing developing time by one-third. (This is done in some processors by adding one additional rack in the first developer.) Using the Model 1411 or 1811 Versamats, you change the film speed by increasing the temperature only.

This solution can be both overreplenished, and underreplenished, so it is important that you calibrate and monitor the flow-rate-meter accurately during operation. The mixed solution keeps up to 14 days in a storage container with a floating lid.

First stop bath. Most photographic developing agents are active only above a certain solution pH. Stop baths drop the pH of the emulsion to a point at which development stops, thus controlling the time of development. As long as adequate replenishment is maintained and the pH remains at the proper level, there are no variables significant enough to affect image quality. However, underreplenishing or omission of the first stop bath results in a loss of density.

Color developer. This step competes with the prehardener for position as second most important in the color reversal process. The color developer is a multipurpose solution that produces the colored dye image (the end product of the process). As the film leaves the wash just before this step, it holds a negative image in metallic silver. The remaining unexposed and undeveloped silver halides form (in effect) a positive image of the original scene. All developing agents oxidized during the first development are removed by the wash. The purposes of the color developer are to expose (fog) the remaining silver halides chemically, to develop the exposed silver halide to metallic silver (producing oxidized developing agents in the image areas), and to form a dye image. This last function is made possible by the by-products of the development reaction. As the silver halide is developed, it produces by-products in the form of oxidized developing agents, which couple with organic molecules in each emulsion to form visible dyes. Since these dyes form only in the vicinity of the recently fogged and developed silver halide, they form only in areas that received no initial exposure. Virtually all the silver is developed, but dyes are formed only in areas that weren't developed by the first developer. The dyes formed are the complement of the color to which that layer is sensitive. That is, cyan dye forms in the red-sensitive layer, magenta dye in the green-sensitive layer, and yellow dye in the blue-sensitive layer.

Probably the single most important variable in the color developer solution is its pH. If better buffering agents were available to control this characteristic, many control problems would disappear. Diligence in maintaining the replenisher pH at a standard level and in controlling replenishment rates probably does more to minimize problems than anything else.

Kodak Reversal Agent RA–1 (TBAB) is *a very toxic* chemical requiring safety precautions in its handling. This chemical comes in either powder or tablet form. When it's in powder form, handle the RA–1 with extra care to reduce the chance of inhaling any dust when mixing the developer solution. Don't let it contact your skin, because it is *readily absorbed through the skin*. If contact does occur, wash the affected area immediately with large quantities of water and a neutralizing soap such as Phisoderm (available from the base hospital or medical supply).

RA–1 (or TBAB) slowly releases hydrogen gas, whether it is solid or in solution, so always store it in polyethylene containers, never in glass. (Polyethylene is porous to hydrogen, thus preventing any buildup to pressure.) Kodak recommends that these tablets or powders be dissolved in water, using either a polyethylene bottle as a shaker or using a polyethylene cylinder on a man-mixer.

The color developer affects the color balance of the final product, so you must closely monitor its time, temperature, and pH. Low temperature gives the film a greenish appearance (low-magenta dye density), while high temperature produces the opposite effect. Low pH produces a very blue appearance because the yellow dye density is lowered and the magenta dye density is increased. High pH produces the opposite effect.

Since pH is the best control of color balance, it is normally adjusted to keep the blue and green color spread to a minimum. One ml of *7N* NaOH per liter of developer reduces the spread (lowers the green and raises the blue) approximately 0.10 density units. One ml of *7N* H^2SO^4 raises the green and lowers the blue approximately the same amount. Color developer can be both overreplenished and underreplenished, so you must calibrate and carefully monitor the flow-rate-meter.

Second stop bath. The second stop bath is used, first, to lower the pH of the emulsion so that the color development reaction will stop and, second, to remove the oxidized CD–3 (color developing agent) from the film. This stop bath is chemically the same as the first stop bath.

After use, this solution has a brownish appearance. This is the result of the carryover of the color developer and normally causes no detrimental effect. As long as adequate replenishment is maintained, no problems should result. However, underreplenishment may allow CD–3 to be carried over into the bleach, where it reacts and forms a magenta stain in the highlights of the film. Both stop baths can be underreplenished but *cannot* be overreplenished.

Bleach. As the film leaves the second wash, it holds a large amount of metallic silver; in fact, almost all the silver halides originally coated into the emulsions have been converted to silver metal by one of the developers. The dye image also exists, but the high concentration of silver makes it almost impossible to detect. The purpose of this solution is to convert all the metallic silver grains back into silver halides which are soluble in a sodium thiosulfate solution. The agent used in the bleach solution must be able to oxidize the silver in the presence of a halide without attacking the dye images. Oxidizing agents commonly found in black-and-white reversal processes, such as potassium permanganate or potassium dichromate, usually attack the dye images. In the color process, the silver images are normally bleached with a ferricyanide bleach solution.

The metallic silver is oxidized by the ferricyanide to produce silver ions, which immediately combine with the bromide ions. This reaction yields silver bromide, and the ferricyanide is reduced to ferrocyanide. Since the bleach solution contains bromide ions in an excess amount, most, if not all, of the silver within the emulsions is converted to silver bromide during this treatment step. The silver bromide is removed in the following fixing bath and washing steps. The bleach also removes the colloidal silver (yellow filter) layer, along with the antihalation backing (if any).

The bleaching step of the process introduces only a few minor potential variables. So long as you keep the pH high enough and maintain adequate replenishment, no problems should occur. Low pH can cause a bright blue stain, which is easily recognized. Underreplenishment results in incomplete removal of metallic silver and is marked by high densities, along with a cyan stain. Also the red and magenta colors appear dark.

Sodium ferrocyanide corrodes most metal containers, so don't leave it in contact with these metals any longer than necessary. It is very corrosive on type 316 stainless steel, so this material cannot be used in the processing machine for the bleach solution. Red brass, polyethylene, porcelain, titanium, rubber, or Hastaloy C stainless steel can be used with this chemical. Most pumps and moving parts are made of Hastaloy but are very expensive. Many machines use red brass to line the machine bleach tank and polyethylene and tygon tubing for the storage and replenisher lines. In the model 1811 processor, both the bleach and fix tanks are made of Hastaloy.

This solution can be underreplenished but *cannot* be overreplenished. As this chemical costs over $183 per 100 liters, monitor the flow rate to prevent excessive overreplenishment.

Fixer. The tanks for this chemical must be the same type material as is used for the bleach because of solution carryover. As the film enters the fixing solution, it contains the dye images and a large amount of silver halides. These halides are, of course, light sensitive; but unless developing agents contaminate the bleach or fixing solutions or the film remains in the light for a considerable time before fixing, the silver halide is dissolved before it can be converted to silver once again. The purpose of the fixer is to convert all the silver salts to water-soluble compounds. One of the most commonly used fixing agents is sodium thiosulfate.

The thiosulfate ion combines with the silver ion to form a soluble silver complex. Most of these silver complexes are removed in the fixing bath itself, leaving only the positive dye images in each emulsion.

Few, if any, variables are introduced by this solution. Properly replenished, it performs adequately, and the concentration of its constituents is not critical. However, underreplenishment leaves traces of silver halides in the film which, on continued exposure to light, will photolyze to metallic silver, causing the final image to darken as it ages. Also, inadequate fixing may cause a yellow stain, noticeable first in the highlight areas.

Stabilizer. In the last wet step of the process, the stabilizer reacts with any unused coupling agents in the film to form colorless complexes, which (unlike the unreacted couplers) do not stain with age. Here the reaction between formaldehyde and the coupler under alkaline conditions (so carefully avoided in the prehardener) is put to good use. The purpose of the stabilizer is to harden the emulsion, which causes minimum absorption of moisture after drying. The stabilizer also helps make the dyes more stable, hence its name. This solution also contains a wetting agent such as Photo Flo to promote even drying. So long as replenishment is adequate, there are no significant variables. Do not wash the material after stabilizing; this destroys the dye-keeping properties.

As this solution contains formaldehyde, *handle it with caution*. The EA-4 process does not use a separate stabilizing bath, as does the EA-5 chemistry. In the EA-4 process, the stabilizer is in the fixer solution.

Any tank containing stabilizer should be dumped weekly, cleaned, and refilled. If you notice a scum deposit on the film, you may have to change this solution more frequently. Due to the relative low cost of this solution, it has proven beneficial to dump and flush the stabilizer tank with warm water after each shutdown. This is normally done only if the processor is to be down for extended period of time. The stabilizer is refilled only at the time of the next startup. The unused stabilizer keeps indefinitely. It cannot be overreplenished but can be underreplenished.

Exercises (241):

1. What is the function of the prehardening solution?

2. Why is the prehardener step a critical one?

3. What is the purpose of the neutralizer?

4. An increase in either developing time or temperature in the first developer does what to the densities of the final dye images?

5. An increase in pH in the first developer does what to the contrast of the final dye images?

6. How can you increase the effective film speed?

7. What is the purpose of the first stop bath?

8. Why is the color developer a multipurpose solution?

9. What kind of fogging takes place in the color developer with EA-5 chemistry?

10. Give the two reasons for the second stop bath.

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11. Underreplenishment of the second stop bath may allow the CD–3 to be carried over into the bleach to cause what color stain?

12. The bleach solution converts the metallic silver to what kind of a compound?

13. What is the purpose of the fixing solution?

14. What is the purpose of the stabilizer?

CHAPTER 2

Manually Produced Black-and-White and Color Imagery

IF GOOD results are to be expected, the laboratory must be properly equipped and properly arranged. The setup for tray processing print and film material in most respects is identical, but some techniques differ. Here we will focus on these differences.

2-1. Laboratory Setup and Shutdown

242. Give the reason for having wet and dry lab sections and for maintaining proper ventilation in lighttight processing labs.

Darkroom Requirements. It is impossible to turn out good photographic work in a dirty laboratory. The laboratory must be kept spotlessly clean at all times. Thoroughly clean shelves, bottles, walls, floors, and sinks are essential. Chemical particles floating about in the air can be deterimental to your health and most certainly will lower the quality of your work.

Just because a darkroom must be lighttight is no reason that it must also be airtight. Adequate ventilation can be provided with light-trapped ventilators and forced air circulated by fans. When feasible, a laboratory should be kept between 66° and 70°F, with a relative humidity of about 50 percent. This provides a comfortable environment for the worker and an ideal environment for the sensitized materials.

Imagine your laboratory as being divided into two sections—a wet section and a dry section. Make it a habit not to take anything that is wet into the dry section, and also never take anything that must remain dry into the wet section. Hang a dry towel on your belt, and when you need to go into the dry section, make sure you rinse and dry your hands. This prevents sensitized materials in either section from being ruined by exposure to the wrong environment.

Aprons (preferably waterproof) should be worn to protect your clothing, and soiled aprons should be given a thorough cleaning. It should be standard practice to have a towel handy at any time that you are processing materials.

Exercises (242):

1. Why should a lab have separate wet and dry sections?

2. Why is proper ventilation required in processing laboratories?

243. Apply given procedures for arranging equipment and trays to account for or prevent accidents during film processing.

Equipment Arrangements. Since most of the films you will use are sensitive to all colors of light, most of your work will be done in total darkness (no safelights may be used when film is out in the open). Therefore, make it a rule to have a place for everything and keep everything in its place. This is important so that you may find items in total darkness and so that you can move about safely within the laboratory. Place the timer in a spot where you can reach it, and make sure you know where the trays are located. Not only must you know where the trays are, but you must also know which is which. If you hang a towel near the developer tray, you can easily find it in the dark. If you accidentally place film in the fixing bath before it is developed, you will get completely transparent film—no picture. All of the silver halides (both exposed and unexposed) are changed to water-soluble silver salts in the fixer. If that happens, no amount of development can ever produce a visible metallic silver image. It is gone forever.

There are certain things that you must do before you are ready to develop the film. It is essential that you standardize the preparatory work to the point where it becomes a habit. Unless there is a special reason for deviating from the suggested pattern diagramed in figure 2-1, arrange your processing trays in the sink as shown. When you follow a set pattern for tray arrangement, there is little danger of accidentally getting the film into the wrong solution.

Some photographic trays have a raised X on the bottom surface of the tray, so that the material to be processed is held away from the bottom. This type of tray should be used for the developer solution, since it is in the developer that the film has its greatest tendency to stick to the bottom of the tray. The raised X also helps you identify the tray in total darkness through your sense of touch.

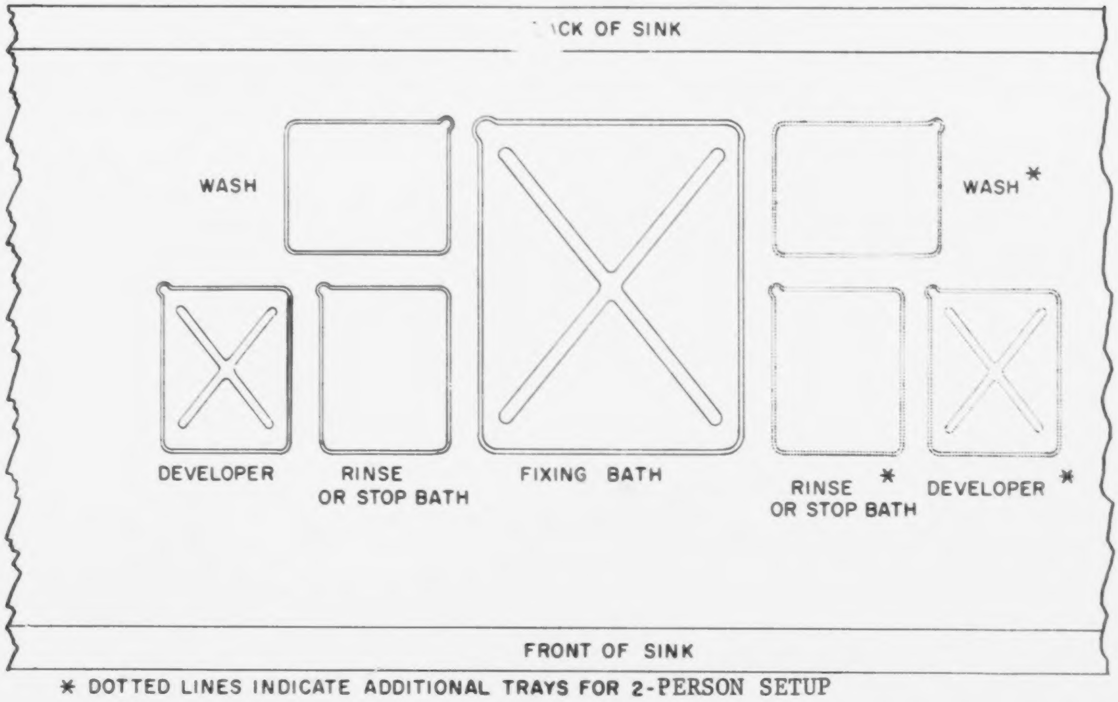

Figure 2-1. Tray layout for film processing.

Exercises (243):

1. Someone else set up your processing lab for you. You assume that it was set up correctly. However, all processed film is clear. What probably happened?

2. What two things can be done to insure that you place film in the developer first?

244. Identify the cause of processed film defects due to improper laboratory setup.

Filling the Trays. In processing the larger sizes of cut film, such as 4- by 5-inch or 8- by 10-inch cut film, fill the tray with about 40 ounces of working solution prepared according to the dilution ratio (if one is specified) for the developer being used. *Be sure all trays are clean!* If the tray used for the developing solution is contaminated with an acidic solution, the effectiveness of the developer will be decreased. In such situations, you can expect products of decreased density and unevenly developed images.

Fill the wash tray with water and submerge it and the water-feed hose in the tray. The flow of water should be enough to circulate the wash water in the tray. A heavy flow of water is not necessary, but the water must circulate enough to assure that the chemical-laden water (which tends to settle to the bottom) is continually replaced. Also, be sure that the temperature of the incoming water is approximately 68°F. If the hot water were accidentally to flow into this tray, the emulsion on the film might be softened enough to separate from the base.

In most cases you should use water in the rinse tray. The water rinse merely dilutes the developer in the film to minimize the shock of going from an alkaline to an acidic state entering the fixing bath. Without this dilution action, the sudden change to the acidic state could cause pinholes in the negative.

For the fixing bath, fill the largest tray with enough solution so that the negative can be easily and completely submerged (usually 1 to 2 inches). Be extremely careful not to splash fixing bath into the developer tray.

Finally, check the solution temperatures. Unless you have other specifications from the developer manufacture, hold the temperature of the developer, rinse, and fixing baths at 68°F. Also, if possible, hold the wash water at this temperature; however, you can use slightly cooler water. Try to keep the wash water between 60°F and 68°F. You can raise your solution temperature by setting the entire tray of solution into a hot water bath, or lower it by using a cold water bath. Be careful to keep the water from spilling over the edge of the trays and diluting the solution.

Interval Timer. Since you process most film in complete darkness, you need to use some kind of timing device. An ordinary wristwatch or clock will not do, especially if you cannot see the hands and figures in the dark. If possible, use an interval timer designed for photographic purposes. Most timers of this type can be preset to any desired time. Then, when you are ready to process, simply start the timer. When the preset time has elapsed the timer gives some kind of signal.

You should have a fixed position for the timer, preferably near the sink where you do your tray processing. It should never be necessary to hunt for the timer after the lights are turned off. If the timer is always in the same place, there is no need to grope around in the dark.

Safelights. Before processing, you must determine what safelight illumination, if any, you can use during the development process. You should check to make sure that the lamps are burning in the safelights you intend to use. Also, be certain that the safelight is "safe" for the particular film you are developing. If not, it could cause a slight base fog.

Exercises (244):

1. Match each negative defect in column A with its probable cause in column B.

Column A

____ (1) Weak image with uneven development.
____ (2) Emulsion separating from the film base.
____ (3) After fixing and washing, small clear areas are evident in the negative.
____ (4) Slight base fog.

Column B

a. Negatives were taken from the developer directly to the fixer.
b. Wash water too hot.
c. Improper safelight illumination.
d. Developer tray contained dried fixer.

245. Given illustrations of processing tray arrangements, select the one that is most appropriate for print processing and state why.

Arranging the Trays For Prints. The tray arrangement for the processing of prints is almost identical to that used for tray processing of film. You should use trays that are slightly larger than the print being processed. Oversized trays are advantageous when many prints are to be processed, since the developing solution will not tend to change temperature or deteriorate as rapidly in a large quantity as it will in a small quantity. A very large tray is preferred for the fixing bath in order to accommodate a large number of prints at any one time. Also, the wash tray should be larger, since it is used as a holding tray for prints that have been fixed and waiting to be placed in a print washer.

Exercises (245):

Use figure 2-2 to answer these exercises. If necessary, refer to the text for objective number [illegible] 243 for more information on this subject.

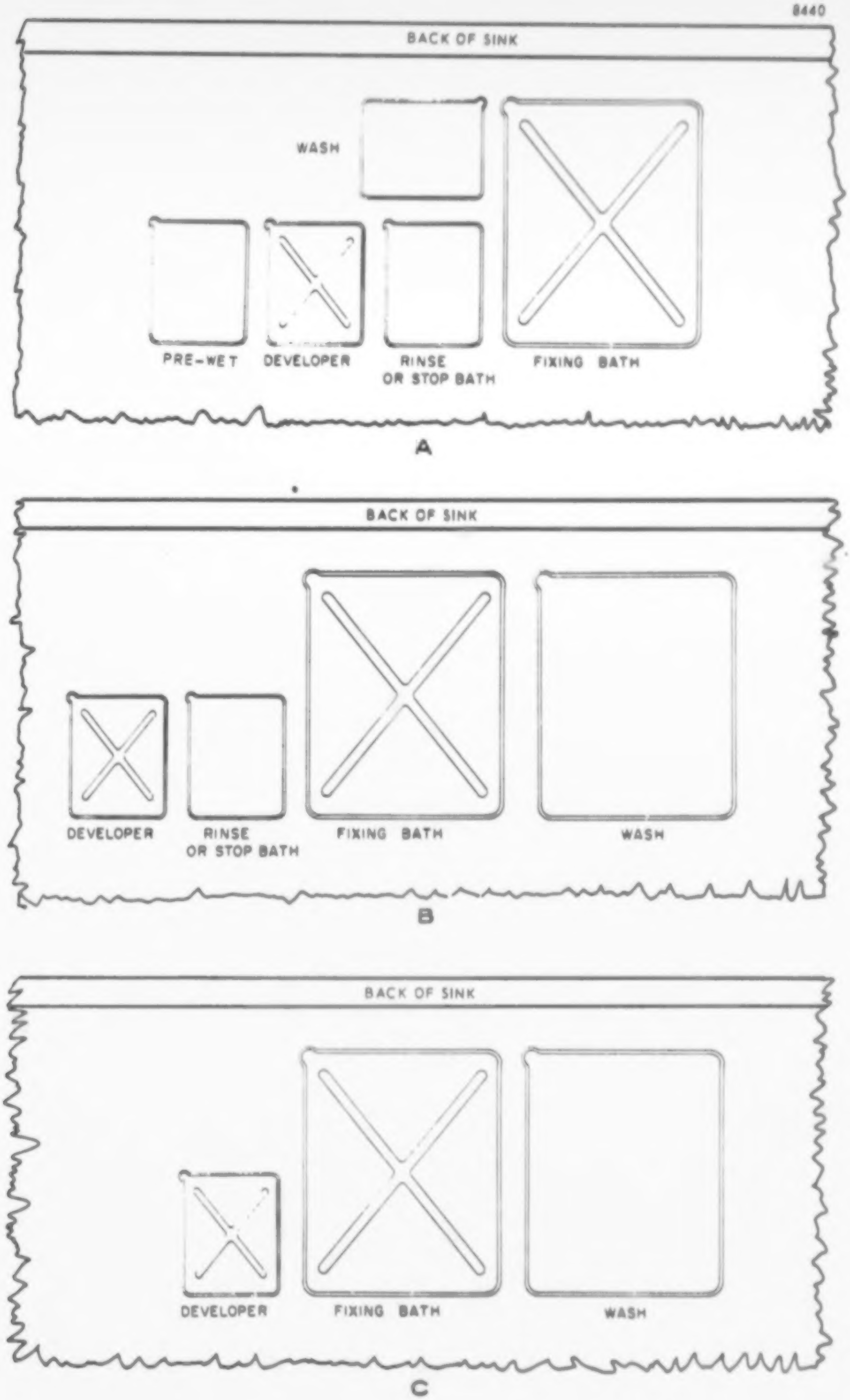
8440
BACK OF SINK
WASH
PRE-WET
DEVELOPER
RINSE OR STOP BATH
FIXING BATH
A
BACK OF SINK
DEVELOPER
RINSE OR STOP BATH
FIXING BATH
WASH
B
BACK OF SINK
DEVELOPER
FIXING BATH
WASH
C

Figure 2-2. Tray layout for print processing (objective 245, exercises 1 and 2).

1. Which tray arrangement would be best for print processing?

2. Why are the other two arrangements not recommended?

246. Given defects related to improper laboratory setup, state the cause of these defects.

Timer and Safelight. A continuous timer (not an interval timer) with a sweep second hand should be mounted over the sink in a location where it can be easily seen. Because a print-processing procedure can be carried out under safelight conditions, it is easy to watch the clock while you are handling the prints in the various solutions. You will remember that black-and-white prints can be processed under fairly bright illuminations provided that the light is of the correct color and intensity. As previously mentioned, you can use a safelight filter, such as the Wratten series OA, for graded-contrast papers. Variable-contrast papers are safely handled under an orange-brown safelight, such as the Wratten series OC or the DuPont S–55X. One thing that you must remember in using safelights is that the safelight filters are designed for use with a definite lamp intensity and at a definite distance. If too large a lamp is used or if the distance is to close, the intensity of the safelight illumination may be too great to be safe. Thus, the sensitized material may be fogged. Using graded-contrast paper instead of variable contrast under the conditions given usually eliminates fogging.

Filling the Trays. Before you process your exposed paper, you must have properly prepared the various solutions. Before you fill the processing trays, make sure they have been thoroughly cleaned. This prevents contamination of solutions. The developing tray for 8- by 10-inch prints should be filled with about 48 ounces of working solution. A typical working solution of this type is compounded at a 1:2 dilution ratio by using 16 ounces of Armed Forces Developer Number 25 (D–72 type developer) and 32 ounces of water. Dilution ratio is 1:2 for normal processing of contact printing paper, but this developer also works well at dilution ratios from 1:1 to 1:4. Remember that the undiluted developer is called a stock solution and the diluted developer is called a working solution.

When you process prints you will often use an acid stop bath in the rinse tray to stop development, help prevent stains, and prolong the life of the fixing bath. You can make an efficient stop bath by diluting 28 percent acetic acid to a ratio of 3:64; that is, three parts of 28 percent acetic acid to 64 parts of water. The dangers encountered when the acid-to-water ratio is too high, or the wrong type of acid is used, are the same as they are for stop baths mixed solely for use during film processing. That is, you can expect such things as blisters, pinholes, or other forms of emulsion ruptures caused by the rapid formation of carbon dioxide bubbles during neutralization. (Whenever you use an acid stop bath, be sure not to splash it into the developer or carry it over into the developer by contaminated hands.) When you can't use an acid rinse, be sure you use a water rinse and change the water in the rinse tray frequently.

Be sure the fixing-bath tray is filled to a sufficient depth with a fresh acid-hardening fixing bath. Be careful not to splash fixing bath into the developer, as it will contaminate the developer and create problems. Now set up the wash tray as you would for washing negatives. That is, submerge the water hose in the tray with enough water flow to circulate, remove the contaminated water, and agitate the prints in the tray.

Be sure you check the temperature of all the solutions. Try to have all temperatures adjusted to 68°F, and use at least 1/2 inch of solution in all trays to insure that the print will be fully submerged.

Exercises (246):

1. Stains are being produced on prints. What improper laboratory setup procedure could cause this?

2. A slight fog is being produced on prints. You are using an OA filter at the correct distance and lamp intensity. What is the probable reason for the fog?

3. The emulsion is frilling on your prints. What is the most likely cause?

247. State the task used in laboratory shutdown procedures.

Observing proper laboratory shutdown procedures is essential to quality production. Maintaining a clean environment while you work saves time and materials and helps insure that you are able to produce a high quality product. No area should be overlooked. While you are working you must insure that the dry section and its equipment does not become contaminated with chemicals. If this happens, stop your production and correct the situation, as many defects are caused by a lack of cleanliness. After you have finished production, laboratory shutdown begins.

Material Disposal. Always return all reusable chemistry to its original place. Some developers and stop baths are for one time use only, if so, dump these according to your particular lab procedures. The fixer should never be dumped, because it contains silver that can be recovered. Film and paper also contain silver and should be saved for silver recovery. When you're handling classified materials, never discard them yourself. Insure that all waste films and papers are taken from the lab, bagged,, and tagged then disposed of by your unit's procedures.

Equipment Care. Laboratory equipment such as safelights and timers should be unplugged and wiped down. The printers should be unplugged and dusted. If the printer is a projection printer, the bellows and printer head should be lowered, and if it is a condenser type printer, the condenser door should be closed. Cover it with a dust cover. All tanks, reels, and thermometers should be cleaned, dried and stored.

Lab Cleaning. Clean and dry the sink and all used trays, leaving no chemical deposits. An uncleaned tray could contaminate the next person's mission. Wipe down all counters and shelves. The floor should be dust mopped and then wet mopped to help minimize unnecessary particles in the air. Always leave the lab clean and the equipment ready for setup.

Exercises (247):

1. How do you shutdown a condenser-type projection printer?

2. How do you dispose of classified waste material?

2-2. Selecting Proper Printing Material

The problem of making a positive from a negative transparency or of making a negative from a positive transparency without losing detail or intelligence information is not new in the field of photography. For years the goal of the conscientious technician has been to produce prints with maximum information transfer, but the problem has become increasingly more complex with the passage of time. One of the factors has been increased demand for better image quality; another is the constant increase in the camera-to-subject distances. Further complications have been brought into the printing process by the miniaturization of photographic camera equipment and by information storage systems that use greatly reduced images.

There are certain problems related to printing that are general in nature. They are common to any printing, whether it's negative to positive, positive to negative, contact, projection, continuous, or duplicating. One, we are faced with the problem of getting the work out to the user in a minimum amount of time. Two, the quality of the original negative may not always be what we want. Three, there are differences in the emulsions available for producing prints. Four, because of the nature of the job, certain problems are of a recurring nature.

248. State how emulsion speed, print material handling, and processing methods influence the selection of print materials.

Speed of Production. Under the stress of imagery production operations, any time spent in reducing the raw data (in the form of undeveloped film) to the final working positive must be held to the minimum. Ideally, the planning, interpretation, and intelligence personnel should have intelligence data immediately, preferably as it is being obtained. But the photographic process takes some time and we must seriously consider the factors that promote a faster flow of information out of the laboratory into the hands of the user. To establish an effective deterrent force, situation assessment must be continuous, and *avoidable* delay in producing materials for the situation assessment is intolerable.

It is sometimes difficult to pinpoint the variables that control production speed, mainly because speed and quality are so often interlocked. If all the factors are considered and either speed or quality must be sacrificed, then the decision as to which factor is the most important and its total significance on the final product will be extremely important. Some of the common factors that affect production speed are the nature of the transparency, the nature of the printing equipment, the speed of the emulsion, the intensity of the printing light, the handling to be given the print, the processing times, and the minimum quality acceptable for the job.

Printing emulsion speed. The speed of print production is dependent (among other things) on the sensitivity of the emulsion used to record the image. All other factors remaining constant, the less sensitive to light the emulsion is, the slower the production of prints. Although this may be insignificant in printing one individual negative, it's important when you're making great numbers of prints. Don't forget the characteristics of emulsion speed, though. High emulsion speeds are gained at the expense of other desirable emulsion qualities, such as fineness of grain. In the effort to gain printing speed through changes in sensitized materials, you may have to sacrifice some of the image quality.

Handling print materials. The time devoted to handling print materials before, during, and after exposure also affects the total production speed. Roll-type materials that can be used with printing and processing equipment are more easily handled than materials in individual sheets. The advantage of using roll-type paper materials with variable-contrast emulsions has become apparent. As long as roll-type material only came in graded contrasts, the time spent in changing rolls often defeated the timesaving advantage of having the material in roll form. This was especially noticeable if a series of negatives had great variations in contrast.

Regular paper-base materials, as a general class, take more handling time than do water-resistant-base positive materials or positive film. Negative-type, transparent-base materials, generally take more handling time than do the positive-type, transparent-base materials because of their thicker emulsion coatings.

Processing times. When long runs of prints are being made, the processing-time variations for the different types of material can have a considerable effect on the total printing and production time. We can easily see why so much research has been done on ways to shorten processing times by using specialized equipment, modified formulas, elevated temperatures, etc. A specific example makes the problem obvious.

Let's say we have 10,000 feet of negative material to print. One print is made on a positive material that takes only 2 minutes of development. Another print is made on a positive-transparency material that takes 10 minutes of development. The difference seems small, but let's look a little closer at the problem. If the processing machine has 20 feet of material in solution at any instant, we can run the first print at 10 feet per minute, but we can only run the second print at 2 feet per minute. In comparing total developing times, it would take at least 16 hours and 40 minutes to run the first print, while the second print would take 83 hours and 20 minutes. For a ''rush project,'' this is a very significant difference.

As you can see, a great many variables control the delivery time of prints. There are many other factors that we haven't mentioned, but the intent here here is not so much to specify each factor as you make you aware of the *kinds* of things you must consider when speed and quality are both involved.

Each individual printing problem requires you to consider these variable factors. It's often hard to tell just which approach you should take, especially when quality may be more important than speed, or speed more important than quality. This may take consultation between the laboratory chief and the interpreter (or the other user). The problem of speed versus quality is always with us, and the 5-, 7-, and 9-level technicians must be well prepared to discuss the possibilities and probabilities of the various alternatives.

Exercises (248):

1. If you must use a high-speed printing emulsion to speed production, what photographic characteristic must you be willing to sacrifice?

2. What is the ideal choice for material and equipment if your laboratory has to produce 20 prints each of 100 consecutive aerial negatives from a roll?

3. If your laboratory needs 100 prints each of several negatives, should you use roll-type, or sheet-type, paper for processing? Why?

249. Name the factors that can cause or correct variations in negative density and contrast.

Negative Quality. Not every negative we have to print will be the ideal negative in all respects. Minor deficiencies due to variations in controlling exposure are common. Other deficiencies are due to the inherent characteristics of individual materials. Naturally, development of the negative should be the best possible, but even perfect development may still produce a negative that is far from ideal. In many cases, only the best possible printing equipment and superior operating techniques can salvage the recorded intelligence data.

Variations in density. Exposure conditions vary, and under certain operational conditions, compensation for the variations at the time of exposure may not be possible. Many variations in overall density might be found on the same roll of negative material. These variations might be caused by changing light conditions, changes in atmospheric conditions, or even equipment deficiencies or unforeseen malfunctions.

Truly important information is just as necessary on an underexposed or overexposed piece of film as it is in an ideally exposed film. Just because the density of the image on the original camera negative is not ideal is no reason for the film to be discarded. If the image is salvageable and contains important information, it is essential that its information be preserved (or possibly even enhanced) in the printing. When such conditions as extreme variations in exposure or contrast arise, the automatic-exposure, automatic-dodging-type printer can usually salvage the most information. This type of printer does a very good job of reproducing detail from both extremely dense highlights and extremely thin shadows.

Variations in contrast. Quite often, while you're producing high-quality work, you must make prints from negatives that have great variations in contrast. (Remember that there are innumerable factors which can cause contrast variations.) In general, the negatives exposed from very great distances and extremely high altitudes have much lower than ideal contrast. As the distance from the camera to the subject increases, the contrast decreases. This loss of contrast can result from several different contributing factors. It is well known by those accustomed to dealing with space and interplanetary distances that the light traveling across great distances (especially through great depth of the atmosphere) is subjected to many things that cause image deterioration.

Particles of aerosols tend to reduce the contrast of the photographic image. These minute particles are gases, dust, smoke, moisture, and countless other airborne bits of material. This effect on light is known by the term ''Rayleigh scattering.'' The reduction in brightness contrast increases with distance and with the height of the camera from the earth, and the rate of increase can be calculated. Since this low contrast in the camera negative may reduce the ability to detect target information, you may have to build up or enhance the contrast in printing or duplicating.

Exercises (249):

1. What happens to contrast as the distance between the camera and the subject increases?

2. What kind of printers best salvage film with variations in exposure or contrast?

2-3. Preoperational Inspection of Manual Contact Printers

One method of producing photographic prints is by contact printing. As you know, contact printing produces prints the same size as the negative. Even though manual contact printers are simple in design, they are very effective in producing high-quality photographic products.

As with any piece of Air Force equipment, there are certain preoperational checks you must make if the printer is to produce as it was designed to do. Let's look now at these minimum preoperational checks. To understand these preoperational requirements better, let's review contact printer operations.

250. Cite basic operation principles of contact printing.

Contact Printers. A contact printer is a lighttight box with an enclosed light source, a ground glass for diffusing light, a clear glass to support the negative, and a platen to hold the negative and paper in close contact during exposure. Closing the platen actuates a switch, which turns on the light to make the exposure. Air Force contact printers range in size from a 10- by 10-inch printer up to a 24- by 30-inch printer. Timing is controlled manually by external devices or by a built-in timer. The basic operation of all contact printers is the same.

A typical Air Force contact printer is the type EN-22A, shown in figure 2-3. This printer accommodates negatives up to 10 by 20 inches, and it has brackets to take aerial rollfilm. Its three-watt incandescent printing lights have individual switches so that you can use any lamp or combination of lamps. There is a built-in, variable-contrast, roll-type filter to use variable-contrast printing paper. At each end of the filter roll, there is a section of clear acetate to use when you are printing on graded-contrast paper. You positioned the filter by rotating the handles at the front of the printer.

A sheet of diffusing glass directly above the lamps gives diffused, even illumination. Above the diffusing glass is a thick sheet of plate glass (the printing glass), to which the negative is fastened for printing. There are three different printing glasses: one clear, one masked for 9- by 9-inch negatives, and one masked for 9- by 18-inch negatives. An inflatable rubber bag attached to the platen of the printer provides uniform contact pressure, and a switch under the platen handle automatically turns on the printing lamps when the platen is closed and locked.

Exercises (250):

1. On the EN-22A contact printer, what activates the exposing lamps?

2. What insures close contact between the negative and printing paper during exposure?

3. What insures even illumination by the EN-22A contact printer?

251. State the tasks in preoperational inspection of manual contact printers.

Preoperational Checks. (These are the minimum preoperational tasks for the manual contact printer.) Clean the printing area first. Eliminate all dust, lint, dirt, and other foreign matter from the printing area. When possible, use a vacuum cleaner, as dusting will merely cause the material to become airborne and in time it will settle back onto the working area. Be sure the printer glass and the rubber platen are clean. Sometimes you'll need to use a lint-free cloth and a small amount of alcohol.

Check the platen for the correct inflation. If it has too much or too little air, correct the situation as outlined in the applicable technical manual. Improper platen inflation, either over or under, can be detrimental to both the printer and the photographic product. If the pressure is too high, the glass may break, resulting in glass fragments penetrating the platen and rendering it useless. If the platen is underinflated, there won't be enough pressure to keep proper contact between the negative and printing material. As a result, fuzzy corners will be evident on the print.

Connect the timer to the printer and then to the proper receptacles. Place all the printing-light switches in the ON position and check the operation of all lights to insure even illumination. Check the viewlights and the safelights in the printer for proper operation. Place the master switch in the OFF position and check the operation of the platen-actuated pushbutton switch.

Exercises (251):

1. What are the dangers of printer platen overinflation or underinflation?

2. Why is a vacuum cleaner recommended to clean the immediate printing area?

3. Why must you check the operation of all exposing lamps?

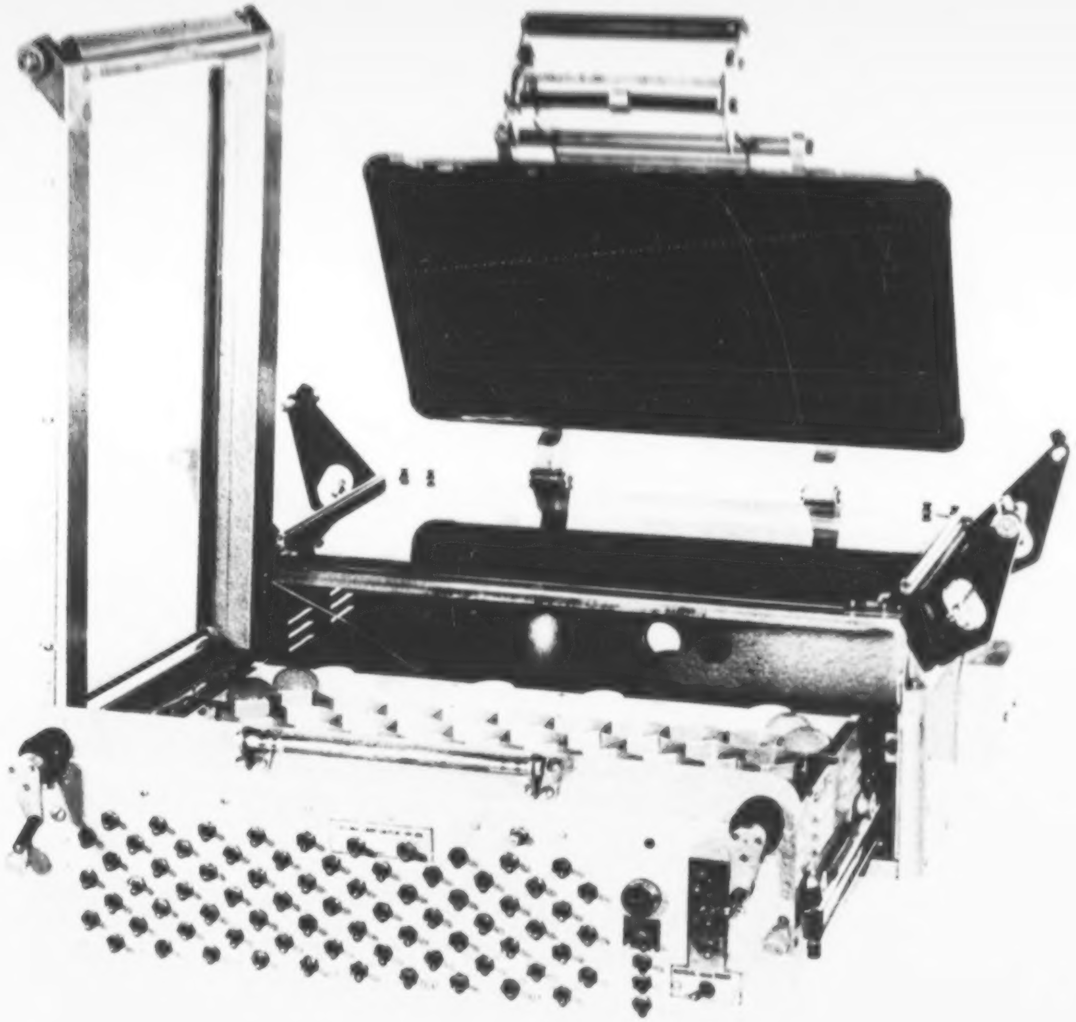

Figure 2-3. Contact printer.

2-4. Preoperational Inspection of Manual Projection Printers

Another method for producing photographic prints is projection printing. Projection printers are either verticle projection or horizontal projection. Most of our discussion in this section will be on the verticle-projection printer. Let's start by reviewing vertical-projection printing principles to help understand the need for preoperational inspection.

252. State how print image size is affected by altering negative-to-lens distance and lens-to-paper distance.

Projection Printing Principles. Projection printing differs from contact printing in that the negative is separated from the sensitized paper. The image on the negative is projected by incandescent light through an optical system onto the sensitized paper. By altering the negative-to-lens distance and the lens-to-paper distance, you can reduce, maintain, or enlarge the image size. Because most projection prints are made at an enlarged scale, it is common to refer to projection prints as "enlargements" and to call a projection printer an "enlarger." (The preferred term is "projection printer," since it can also reduce.)

Today the skill of making prints by projection has become as necessary to the laboratory specialist as making contact prints, because projection printing can regulate the size of prints, regardless of the size of the negatives. Other advantages are the ability to improve perspective, the ease of dodging, the large choice of commercial paper surfaces, and the many and varied special effects you can get.

In projection printing, several things influence the projected image size. One is the projection lens. For any printing plane (easel-to-negative distance), the shorter the focal length of the lens, the larger the projected image size. Also, for any given lens, the greater the distance between the negative and printing plane, the larger the image size. If you need precise, projected image sizes, you might need several tries to get these exact dimensions. The reason for this is quite simple. Focus depends on the ratio of the printing plane-to-lens and lens-to-negative distance. As the projected image size changes, this ratio changes, causing an out-of-focus image. You must readjust the position of the projection lens to keep the proper focus. Moving the position of the projection lens during the refocusing step will change the projected image size slightly.

Exercises (252):

1. To increase the projected image size should the projection printing lens be farther away from, or closer to, the printing image?

2. Will a longer, or a shorter focal length projection lens decrease the print image size?

253. State remedies for common problems during vertical-projection printer setup.

Vertical-Projection Printer Preoperational Inspection. Several things must be done before you use this type of projection printer for production work. First, clean the working area thoroughly. Be sure that all equipment and facilities are free of dust, dirt, and other foreign materials. Cleanliness is especially important when images are being enlarged. Minor dust particles on the negative or on the glass plates of the negative carrier become extremely noticeable when they're enlarged. Remember, any solid foreign particle on these glass plates will completely void the corresponding area of the print.

Check the projection lens. Get the focal length lens you need for production. Be sure it is free of fingerprints and dust and has no loose lens elements. Insure that the negative plane is parallel to the easel. Any tilt will distort the print image. Check the bellows for light leaks. Any extraneous light will fog prints. Clean condenser lens and be sure it's properly positioned. If it's not, the intensity of light reaching the printing plane will be uneven, decreasing from the center toward the edges of the easel. Connect the timer to the printer and then to the proper receptacles.

Obviously, these aren't all the preoperational checks for projection printers. The list will vary from printer to printer, and these may be special items for the printer used in your facility.

Exercises (253):

1. How can you alleviate these vertical-projection printing problems?
    a. There is a noticeable decrease in the intensity of the exposure light near the edges of the easel.
    b. With the lens diaphragm wide open, the entire print image area is not in focus.
    c. A small area of no exposure appears on prints from several different negatives.

254. State remedies for common problems in horizontal-projection printer setup.

Horizontal-Projection Printer Preoperational Inspection. There are probably many horizontal-projection printers in use today. Two of these are mainly used in your career field at the present time: the Beacon Precision Enlarger, and the Horizontal Enlarger Model HE–12. Our comments will be on the Beacon Enlarger. As with the other type, there are some things you should do before using the horizontal-projection printer for production work.

Clean the work area thoroughly. Be sure that all equipment and facilities are free of dust, dirt, and other foreign materials. Insure that supply and takeup spindles are identical and that they do not exceed 7.6 inches in diameter. Pick the right objective lens assembly for the type of printing. All six objective lens assemblies (A, B, C, D, E, and F) can be used for black-and-white printing. Be sure the condenser lens and lamp assembly match the objective lens assembly. (They're also marked A, B, C, D, E, and F to match the six objective lens assemblies.) When the right lens and condenser combination is installed, the appropriate magnification/focus window on the easel drive assembly will light. Again, we've deliberately left the list incomplete to allow for variations from printer to printer and from lab to lab. Check your local procedures.

Exercises (254):

1. How can you alleviate these horizontal-projection printing problems?

    a. The appropriate magnification/focus window on the easel drive assembly doesn't light when you install the lens/condenser combination.

    b. Problems are occurring in the film tracking.

255. Identify projection printers with their characteristics, and state the type of negative carrier to use for specific size negatives.

Projection-Printer Operation. In general, all projection printers are quite similar in design and operation. They consist of an enclosed light source, some means of distributing light evenly over the negative, a negative carrier, a lens, a means of adjusting lens-to-negative and lens-to-paper distances, and an easel for holding the sensitized paper. There must be some way of changing the lens-to-negative and lens-to-easel distances to provide for different degrees of enlargement or reduction. The degree of enlargement of an image is usually referred to in terms of *diameters*. As an example, a two-diameter enlargement is twice the length and twice the width of the negative image (four time the area); and a three-diameter print is three times the length and width of the negative image (nine times the area).

Most projection printers have tungsten lamps as a light source. The lamp is enclosed in a lighttight housing, which is ventilated to keep excessive lamp heat from damaging the negative. Some projectors have blowers to circulate air and cool the inside of the lamp housing.

The negative carrier may be either a dustless type or a glass-sandwich type. The *dustless* carrier consists of two metal plates with an opening in the center large enough to accommodate the negative. The negative is placed between these plates and is held in position by its edges. This type of carrier is satisfactory for negatives 4 by 5 inches in size or smaller, since they are rigid enough to remain flat. The *glass-sandwich* carrier is a holder with two sheets of glass between which the negative is placed. A holder of this type is necessary for larger negatives, since they have a tendency to sag in the center if they are used in the dustless carriers.

The enlarger lens should be an anastigmat with an angle of field large enough to cover the negative being printed. This means its focal length should be approximately equal to the diagonal of the largest negative to be printed.

The bellows should be able to extend to at least twice the focal length of the lens, allowing production of 1:1 (same size) reproductions. Although it is possible to make reductions to any desired size, the bellows on most projection printers cannot be extended far enough to make reduced projections smaller that 1:1. You can make smaller reductions by substituting a lens of longer focal length, but a more satisfactory method is to use a reducing attachment. This attachment, available as auxiliary equipment on some projection printers, consists of a section of supplementary bellows to which is attached a long-focal-length lens. The regular projector lens is not used in conjunction with a reducing attachment.

There are many types of easels in use, each serving the same basic purpose—holding the printing paper in a flat plane. Most easels have adjustable masking strips to regulate the borders of the prints. Those equipped with masks usually have an adjustable guide for placing the paper evenly under the masking strips and regulating the width of the white border.

The methods used to distribute the light evenly over the negative divide projection printers into two general types; the *condenser* type and the *diffusion* type.

Condenser-type projection printers. The condenser-type projection printer has a set of condensing lenses between the printer light and the negative. These condensing lenses align and project the light rays evenly through the negative. This occurs when the negative being printed contain flaws, scratches, and abrasion marks. Since all features of the negative are being enlarged, you can easily see that the flaws will also be enlarged. A condenser-type printer usually has a faster printing speed that a diffusion-type printer under the same conditions, and it produces a more contrasty image from a given negative.

Condenser lenses are designed and ground to provide maximum image sharpness with a given focal length lens. Therefore, if you change projector lenses, you must also change condenser lenses. Most condenser-type printers have several different focal length lenses and matching condenser lenses. Late model projectors have a variable-condenser system, so that all you must do is change the position of the top condenser lens to match the focal length of the projection lens.

Diffusion-type projection printers. The diffusion-type projection printer has a diffusing medium (usually ground glass) between the light source and the negative to spread the light evenly over the entire surface of the negative. Light from the lamp, as well as that reflected from the parabolic reflector, strikes the diffuser, which scatters it in all directions. Thus, when the light reaches the negative, the light is nondirectional. The effect of using diffused illumination is that minor negative defects are not clearly recorded on the print. There is a general softening of the image sharpness due to a reduction in image contrast. The diffusion-type printer is especially suitable for portraiture and other printing involving negatives 4- by 5- inches and larger.

Exercises (255):

1. State whether each characteristic applies to condenser or diffusion projection printers.
   a. Suitable for portraiture.
   b. Has the faster printing speed.
   c. Provides maximum image sharpness.
   d. Reduces image contrast.
   e. Softens image sharpness.
   f. Allows scratches to be easily seen.
2. What type negative carriers should you use with 4-inch by 5-inch negatives? With larger negatives?

2-5. Printing Test Strips

In printing, two of your major problems are to find the right contrast and the right exposure. In either case, you can get the right results by making one print after another until you finally get what you want. The net result of all this will include a fair-sized pile of unusuable prints coupled with an expenditure of considerable time, effort, and money. It's much better to simplify the whole business by using a test strip.

256. State how we use test strips in printing.

Test Strip Purpose. Test strips are small pieces of paper that are given different exposures to determine the correct amount of exposure and the correct contrast of paper. Their use minimizes the waste of expensive sensitized materials. If you know nothing about judging the density and contrast of negatives, you may have to make as many as 20 or more actual tests to pinpoint the right exposure and contrast. With experience, however, this number of tests should constantly decrease.

Exercises (256):

1. What is the purpose of test strips?
2. What are their benefits?

257. State how to produce test strips.

Test Strip Production. As we said, using test strips to determine exposure and contrast saves a lot of sensitized paper. To prepare the test strips for contact printing, cut a sheet of each grade of printing paper (if graded-contrast paper is used) into strips about 2 inches wide. After some experience, you will be able to get by with even narrower test strips, saving more material.

For your first test strip, make a series of exposures using the normal contrast (2) graded paper or the number two filter with Polycontrast paper. Use a systematic method of exposing. For example, you can start with 2 seconds and double it each time for exposures of 2, 4, 8, 16, 32, etc., seconds. Another method is to expose each test with an equal amount of increase (for instance, 2, 4, 6, 8, 10, etc., seconds). The main thing is to be sure to bracket the correct exposure; that is, go from underexposure to overexposure.

A projection test exposure differs slightly from contact printing in that the series of test exposures are made on *one* sheet (or part of a sheet) of paper. Place the sensitized paper in the easel then first give the entire sheet a 2-second exposure. Second, cover part of the paper with a piece of cardboard or other opaque material, and make another 2-second exposure. Then, move the cardboard to cover still more of the paper and give a 4-second exposure. For the fourth step, cover still more of the paper and make an 8-second exposure. Repeat this procedure until you've bracketed the correct exposure. Thus, after development, there are, on one sheet of paper, several bands with exposures 2, 4, 8, 16, 32, etc., seconds. From this test, you should easily be able to find the right printing time.

Exercises (257):

1. How are contact printing test strips produced?
2. How are projection printing test strips produced?

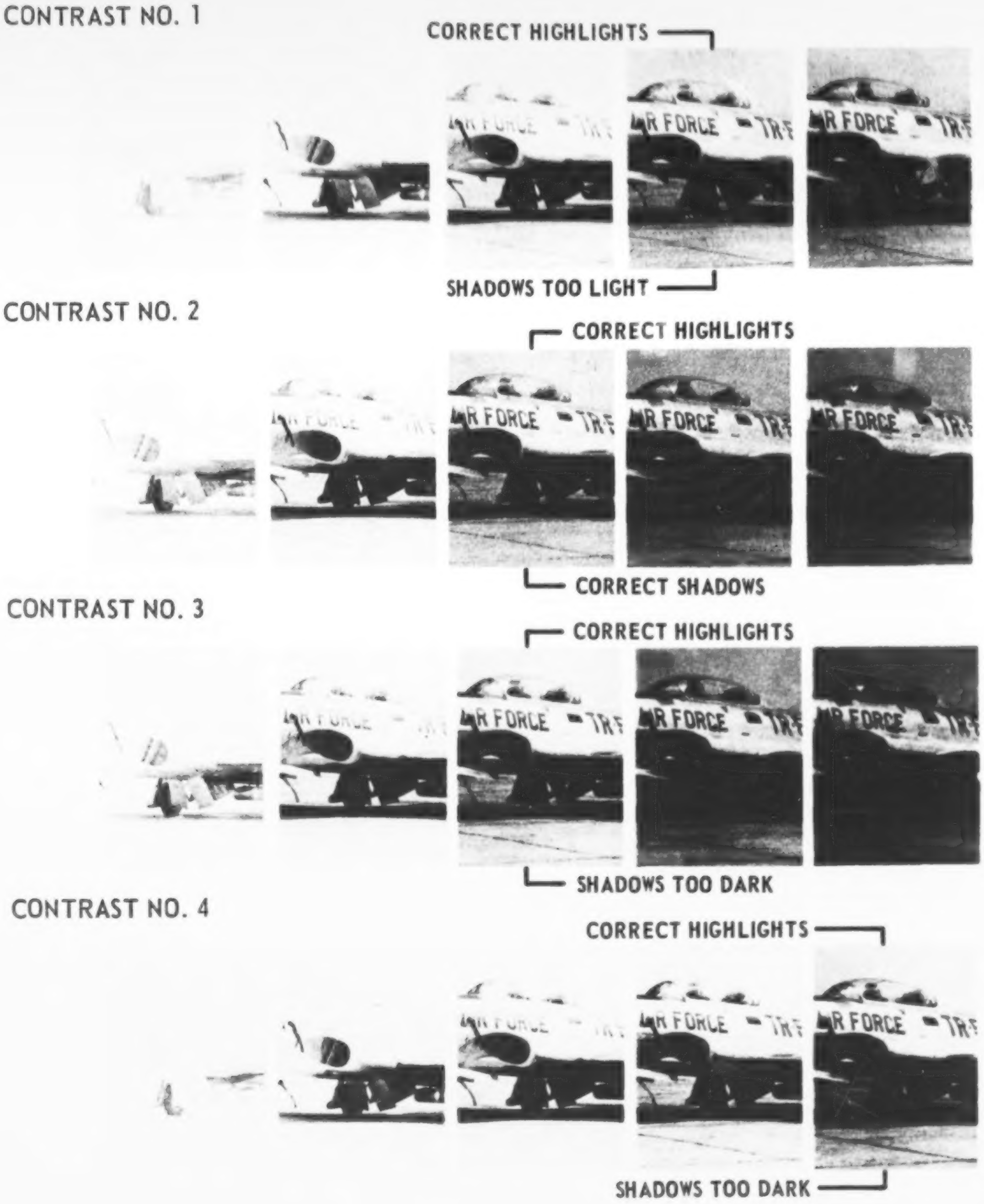
CONTRAST NO. 1
CORRECT HIGHLIGHTS
SHADOWS TOO LIGHT
CONTRAST NO. 2
CORRECT HIGHLIGHTS
CORRECT SHADOWS
CONTRAST NO. 3
CORRECT HIGHLIGHTS
SHADOWS TOO DARK
CONTRAST NO. 4
CORRECT HIGHLIGHTS
SHADOWS TOO DARK
AIR FORCE
TR-F

Figure 2–4. Contact printing test strips.

258. State how to select areas for test strip exposure.

Test Strip Exposure. Before exposing the contact printing test strip, choose the area of the negative you plan to use for test strips. This area for test should contain usable highlights, middle tones, and usable shadow areas. Make each test strip from the same part of the negative. Only in this way can one test be accurately compared with another test strip. Figure 2-4 shows a series of exposure tests on four different contrast grades of paper. Note the fine differences of exposure. If these were actual test strips and you were using them to find the right printing exposure, you would pick the one that shows acceptable detail in the lightest portion of the image that is important. Also from this series of four test strips, you can readily select the appropriate contrast grade of paper or variable-contrast filter.

You cannot use this procedure to find the right exposure and contrast for projection printing, since the full sheet of paper and entire image is used for the test. Instead, make the exposures as we discussed, test the process, and select the best exposure. This selection is entirely subjective and may prove to be wrong, but you won't know until you expose, process, and analyze the print. You can make adjustments in exposure and paper contrast from this print.

Exercises (258):

1. Which area of the contact printing test strip (shadow, middle tones, or highlights) should you use to find the right exposure?

2. Why must you include both shadow and highlight areas in the test strips for contact prints?

3. What combination of shadow, middle tones, and highlight would be best for test strip production?

259. State how to correct typical faults in test strip exposure and contrast.

Test Strip Analysis. After you have exposed your tests on contrast number two paper (or with a number two filter on Polycontrast paper), process all test strips simultaneously for an equal length of time. The time of processing and the temperature of the solutions are usually recommended by the paper manufacturer. It is preferable that you process test strips using some type of easily repeatable agitation, such as you use in processing film. Before processing test strips, you should identify (lightly mark on the back with a soft lead pencil) the test carefully. You must know what contrast and exposure produced the final results.

As soon as you have processed the test strips, carefully inspect them. You find the best exposure for that grade of paper or variable-contrast filter by observing only the highlight area. The highlight areas should contain detail. Too little exposure is indicated when there is no detail in the highlights. Too much exposure is indicated when the highlight areas are much darker than unexposed material. If the highlights aren't right on *any* of the test strips, run a series of tests (same grade of paper and filter) using more or less exposure as is indicated.

When you have selected the best exposure, check the contrast by examining the shadow area that has the right highlight exposure. If the shadow area of this test is too light, the paper doesn't have enough contrast and you need a higher numbered graded paper or filter. If the shadow is too dark, the paper has too much inherent contrast and you need a lower numbered graded paper or filter.

If you find that you used the wrong contrast, run a series of test exposures on a different contrast of paper or with a different variable-contrast filter. If the results of these tests are satisfactory, make the final full-size prints using the exposure time and the paper contrast or filter indicated by the test strip that has both the right highlight and shadow density.

Exercises (259):

1. What changes in exposure or paper contrast should you make based on these test strip analyses?

	Shadows:	*Highlights:*
a.	Insufficient density.	Insufficient density.
b.	Insufficient density.	Acceptable density.
c.	Insufficient density.	Too much density.
d.	Acceptable density.	Insufficient density.
e.	Acceptable density.	Acceptable density.
f.	Acceptable density.	Too much density.
g.	Too much density.	Insufficient density.
h.	Too much density.	Acceptable density.
i.	Too much density.	Too much density.

2-6. Photographic Printing

At this point you are finally reaching the culmination of all your efforts—producing the final product. Up to now, each step of the process was important and none could be slighted. However, do not forget that a print is the ultimate result. Every link in the chain, up to now, could have been strong and perfect, but your efforts will have been in vain if the print is of poor quality. In view of this, let us go through the steps of print production.

260. State the basic steps in making contact prints and give the basic reason for making a mask.

Contact Printing Procedures. Here's the procedure for making contact prints.

(1) Make a mask the right size for the negative you're printing.

(a) The white borders on most photographic prints are made when the paper is exposed. A mask is often made from four strips of opaque material, such as black paper or black cellulose acetate, taped together at the corners to form a rectangular opening. The opening may be 7½ by 9½ inches (for 8- by 10-inch prints) or 3½ by 4½ inches (for 4- by 5-inch prints). A cardboard guide of the right print size can help you adjust the size of the opening and align the individual mask's strips. Needless to say, the opening should be a perfect rectangle.

(b) When you place the mask between the negative and the light source, it keeps light from exposing the edges of the printing material, and so the edges remain white. The mask sizes we mentioned produce a 1/4-inch border on both 8- by 10-inch prints and 4- by 5-inch prints. In addition to the 1/4-inch border, you can make masks that give you borders of any size you want or even of a special shape for specialized purposes. You may want a circular border on a print, in which case the opening in the mask is round. Or, maybe you want an opening shaped like a keyhole or one imitating the effect of looking through a pair of binoculars. Shapes such as these are often used for special effects.

(2) Set up trays for processing in the same arrangement you use for tray processing film. Fill each tray with at least 1 inch of the proper solution.

NOTE: Use Armed Forces Developer Number 25 (Kodak D-72) diluted with two parts water. Eight- by 10-inch trays may be filled with 16 ounces of AFD Number 25 and 32 ounces of water, at approximately 68°F.

(3) Position the mask over the central part of the printing area of the printer. Fasten the mask to the printer glass with four pieces of masking tape, one at each of the corners.

(4) Place the negative on top of the mask with the emulsion side up (or away from the glass). Position the negative so that the image will be portrayed with the best composition possible. Tape the negative to the mask, being careful not to have the tape in the area you wish to print.

(5) Use test strips to find the right exposure and paper contrast.

(6) Process all test strips simultaneously for 1 minute and 15 seconds at 68°F using normal agitation. Before processing, identify the tests carefully; you must know what contrast and exposure produced the final results. You must process the test strips with the same agitation and time of development as the final prints.

(7) Inspect the test strips. Find the best exposure for the grade of paper tested by observing only highlight areas. The highlight areas should be slightly darker than the same paper with no exposure. The highlight areas should contain detail. Too much exposure is indicated when the highlight areas are much darker than the underexposed material. If the highlights aren't right on any of the test strips, run a new series of tests on the same paper using more or less exposure as indicated.

(8) When you have selected the best exposure, check the correct contrast by examining the shadow area of the test strip that has the right highlight exposure. If the shadow area of this test is too light, the paper (or filter) doesn't have enough contrast. You need either a higher numbered graded paper or a higher contrast filter. If the shadow is to dark, the paper (or filter) has too much inherent contrast. You need either a lower numbered graded paper or a lower contrast filter.

(9) Run a new series of test exposures on a different contrast of graded paper or with a different contrast filter (only, however, if the above step indicates that this is necessary).

NOTE: Processing prints manually is much in the same as tray processing. Each print is placed, individually and emulsion down, into the developer solution. However, the shorter development time for paper requires that agitation be constant and submersion be completed immediately. Turn the print over to view the image within 1 minute after its development has started.

(10) Using full-sized paper (according to the negative size), make one print to determine adequacy of dodging (or to establish dodging). Process the test print.

(11) Make the number of prints you need, using the exposure, contrast, and dodging determined by the tests. Be sure to position each sheet of paper on the negative so that the mask will produce an even, symmetrical border. You can use masking tape for a positioning guide. Process the prints, observing the proper development time and the proper developing temperature.

Exercises (260):

1. The first step in contact printing is to make, or insure the availability of, a proper printing mask. What purpose does the mask serve?

2. After the mask and negative are on the printer and the processing setup is made, what is the next step?

3. After you find your exposure and paper contrast from the test strips, what is the next step?

261. List the methods for dodging contact prints.

Dodging Contact Prints. Many exposures are made under less than ideal conditions and may result in wide variations of density in different areas of a single negative. That is, the exposure in one area of the negative is much greater or much less than in other areas. This is usually caused by wide variations in subject tones or the reflective qualities of the subject. In effect, the negative has a greater range of densities than the printing paper can reproduce. As a result, you have a negative that is very difficult to print. If you expose the print long enough to bring out the details in the highlight areas, the shadow areas become overexposed. Or if you reduce the exposure to retain detail in the shadow areas, the highlights will be underexposed and lack detail. Since the objective of photography is to produce an accurate, detailed representation of the subject, you must use special printing controls. Your corrective action is a technique known as *dodging*. Dodging controls the exposure in specific areas of the print; that is, it gives one area of a print less exposure than another area. This can be done in different ways, and a particular negative might call for any one or all of them.

The most common and the easiest method is to the control the individual lights under various parts of the negative. You turn OFF the switches controlling lights under the negative's areas that print too dark and leave ON the lights under the negative's areas that have the greatest density. Thus, these areas of the print get more exposure than the areas of the negative that are above the extinguished lamps. If turning the light OFF for the entire exposure time lightens the areas too much, extinguish them for only part of the total printing time. On the other hand, if turning the lights OFF for the total printing time does not hold the light back enough, you may have to turn OFF some

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of the lamps *surrounding* the thin areas of the negative, as well.

A second method of dodging is to interpose a translucent medium between the light source and the negative. Material such as tissue paper can be torn in the approximate shape and size of the thin area of the negative. This dodging material can be positioned on the diffusing glass directly under the thin areas of the negative. The increased density provided by the dodging material will help hold back the light. You can control the degree of dodging by using translucent material of various densities or by using several layers of the material.

A third dodging method interposes an opaque material between the light source and the thin part of the negative. This way, only the light coming in from an angle can cause an exposure through the thin area of the negative.

When you must do a large amount of dodging, you may have to make compensation, because you're decreasing the total intensity of the illumination. Thus it is wise, whenever possible, to establish the dodging before making the exposure test strip.

Exercises (261):

1. Give three ways to dodge contact prints.

2. If a negative has an odd shaped area of slightly decreased density that requires dodging, what dodging method would be best?

3. How would you block out a complete area of the negative?

262. State the basic steps for making projection prints.

Projection Printing Procedures. The darkroom arrangement for projection printing is basically the same as that used for contact printing. The size of the prints may take larger trays and more working solutions, but the trays should be arranged in the sink in exactly the same order as for contact printing. Armed Forces Developer Number 25 is just as effective with projection prints as with contact prints. It is diluted 1:2 as the working solution for most projection-printing papers. However, the contrast of chlorobromide and bromide emulsions can be varied more by developer dilution than could chloride emulsions (contact paper). Therefore, you can change the dilution of the working solution to 1:1, 1:3, or even 1:4 to get the result you want. Until you gain experience, though, use only developers diluted to the 1:2 ratio. The recommended developing time for processing bromide or chlorobromide papers using Armed Forces Developer Number 25 diluted 1:2, is 90 seconds, with useful times ranging from 60 to 180 seconds.

The prerequisites for good projection prints are good negatives, a clean enlarger, the proper contrast grade of printing paper or variable-contrast filter, correct exposure, and careful processing and finishing. Although most any negative can be printed by projection, there are a few characteristics that are particularly desirable. A good negative has normal density and contrast. It is sharp and free from such defects as scratches, abrasions, dust, lint, and fingerprints.

Always handle a negative carefully by its edges to prevent fingerprints and greasy smudges. Enlarged fingerprints, lint, and dust particles hold back the light during printing, and their shadows produce white spots on the prints, which are very unattractive additions to any photograph. If they need it, clean both the negative and the negative carrier with a tuft of cotton moistened in alcohol or film cleaner. If the negatives are properly processed and handled, however, they can usually be cleaned with a soft brush.

Projection Printing Composition. Place the negative in the carrier so that the emulsion side is down toward the lens. In other words, the base of the negative (the shiny side) should be up or facing the lamp house. Replace the negative carrier in the projection printer and make sure that it is properly seated.

Adjust the paper corner guide and the masking device on the easel to form the border width and print size you need. As an aid for composition and focusing, place a sheet of white paper in the printing position on the easel. The base side of a finished print serves nicely for this focusing screen. Then turn out all white lights. Turn the printer light on and open the lens to its maximum aperture.

Focusing and arranging the composition of the projected image should be done with the lens wide open for two reasons. First, the brighter the image, the easier it is to see for accurate focusing. Second, stopping down the lens *after* focusing causes a greater depth of field and this provides a margin of safety for any slight error in focusing.

Now raise or lower the printer head until the image reaches the approximate size, then get your sharp focus by changing the lens-to-film distance. The size of the image will be changed slightly by focusing, so you should readjust the printer head. This involves moving the enlarger head and refocusing. Repeat this cycle until you get the size image you want and it's in sharp focus. When you raise the enlarger head, you have to decrease the lens-to-film distance as the lens-to-paper distance increases. This keeps the image in focus at any printer head position.

At this point, you are faced with several minor problems. Take a moment and study the image carefully. This picture is easier to compose if the scene is right side up. If it is upside down, either rotate the carrier or remove the carrier and reposition the negative. Most printing papers are rectangular, so your next problem is to decide whether to use a vertical or a horizontal format. The way a scene is composed on the negative is often the controlling factor, but many photographs can be improved in printing by suitable cropping, straightening, tilting, or by some adjustment of the balance of tones. If the photographer made no attempt to compose the picture on the negative,

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you can often enlarge a part of the negative that contains a good picture.

Since photographs have infinite variety, and personal likes and dislikes differ, there are no hard and fast rules in composition. However, here are some suggestions that you can use to produce a composition that is pleasing to most people.

a. Mask off unneeded detail at the edge of the picture. Many times the foreground is fuzzy and is cluttered with objects that distract attention from the center of interest.

b. Never place the center of interest in the middle of the format, but a little to the left or right of center, and a little above or below the center line.

c. Horizontal, vertical, or diagonal lines should never be allowed to cut the picture in equal parts. For example, the horizon should be below or above the center of the picture.

d. The horizon should be truly horizontal.

e. Live subjects should be looking into the picture, not out of it. In other words, there should be more space in front of the figure than behind it. This also applies to action photographs; your composition will be strengthened if the action leads into the photograph and weakened if it lead out of it.

f. Your photograph should appear to rest on a solid base. You can achieve this effect by printing the lower part somewhat darker than the upper part.

g. In a photograph of a landscape, print the foreground darker than the middle distance and the middle distance darker than the far distance. Then gradually darken the sky from the horizontal upwards. This will create an illusion of depth in an otherwise flat subject.

After the image is correctly composed and focused, close down the lens aperture enough to require about 10 seconds' exposure. This length of exposure is ideal because it permits a normal amount of dodging and is fast enough for quantity production. The exact amount the lens should be "stopped down" depends on the density of the negative, and it's hard to determine without experience. For the beginner, it is suggested that the printer lens be stopped down one or two steps from the maximum aperture. Since dust or fingerprints on the lens can diffuse the projected image, clean the optical system with lens tissue. Turn the printing light OFF, remove the white paper from the easel, and place it aside for use with the next negative.

The size of projection prints is limited entirely by the optical system used and the working space available. To a lesser degree, the size of the printing paper governs the size of print. However, a scene may be printed in sections on several sheets of paper, and by splicing these sections together, you can create a picture as large as space permits. The last step is to find the correct exposure and paper contrast as we discussed earlier.

Exercises (262):

1. How is the negative positioned in the projection printer?

2. How are the white borders on projection prints produced?

3. How do you get the right size projection print image?

263. List the methods for controlling exposure on projection prints and state how to prevent obvious evidence of such control.

Dodging and Burning in Projection Prints. We stated earlier that projection printing permits a great degree of print control. Sometimes the brightness range of a subject may be too great to be reproduced in a straight print, but you can usually compensate adequately by shading the area that prints too dark. For example, detail in shadow areas can be preserved by *dodging* during part of the exposure. Dodging is usually easier and more accurate in projection printing than in contact printing.

It is usually necessary to dodge or lighten some parts of most projection prints to produce a correctly exposed image. Since the dodging material is held and manipulated in the beam of light from the lens, its location and coverage can be seen and controlled during the printing exposure. As shown in figure 2-5, the dodging device may be nothing more than your hands. It is surprising how many shapes you can form with your hands. Or, as shown in figure 2-6, a dodging device can be made by placing an opaque, properly shaped piece of material on a wire handle. Dodging is generally necessary for only a part of the exposure time. The dodging device used must be moved up and down slowly and constantly to blend the areas receiving various exposures together, thus preventing a sharp line between the area dodged and the other parts of the image.

Another form of print control, termed "burning-in," is used to darken an area that would otherwise print too light. This is done by using a cardboard or paper with a hole in the center that is smaller but approximately the same shape as they are to be burned in. The device need not be complex. Figure 2-7 shows a simple device in use. After the normal overall printing exposure has been made, the burning-in device is moved into position between the lens and the easel. The card holds back all the light except that passing through the hole to the area that needs more exposure. As in dodging, keep the device in motion while the light is on to prevent a sharp outline of the hole.

You should practice dodging and burning-in before you try to expose the print. Remember the amounts of time that you used for each step in the printing exposure. This is the only way you can control the procedure well enough to duplicate it for extra prints. For example, the entire print may be exposed for 5 seconds; the area to be dodged (lightened) is then covered and an additional 5 seconds exposure is given. Then the part that needs more exposure may be burned in for 5 seconds. Part of the print has received 15 seconds' exposure, another part 10 seconds, and the shadow area only had 5 seconds' exposure.

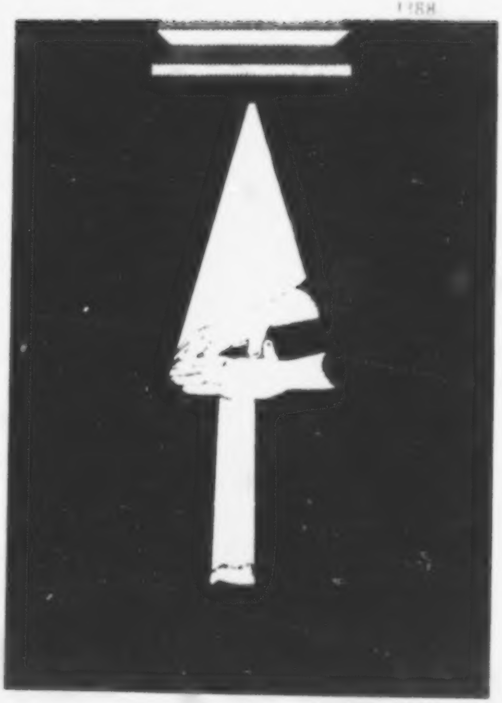


Figure 2-5. Using the hands as a dodging device.

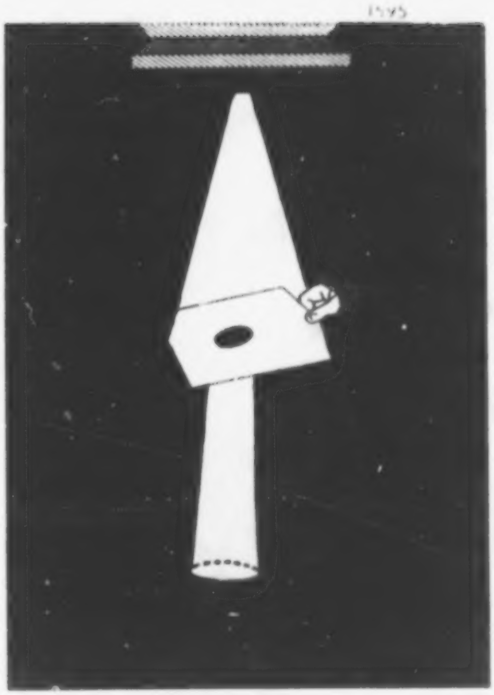


Figure 2-7. Using a burning-in device.

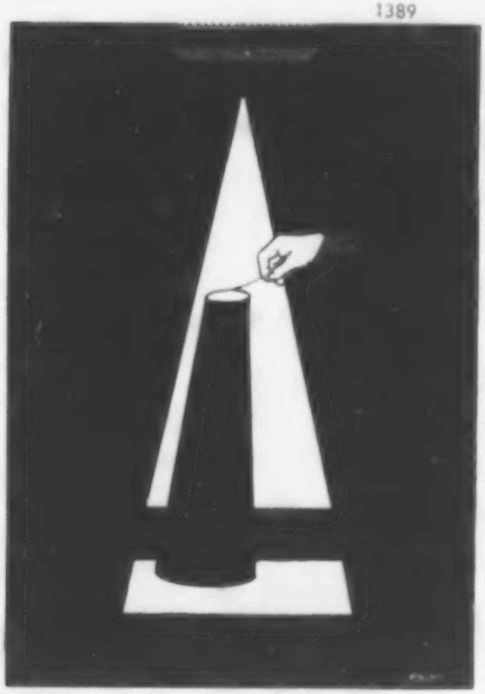


Figure 2-6. Using a wire-supported dodging device.

As you gain experience in all of the dodging techniques, you will also develop your ability to read a negative. That is, by observing the negative, you can judge the amount of dodging you need without having to make text exposures. Before you develop the ability to "read" negatives, you should use test strips.

You can use a small test strip to determine the printing time for the area to be dodged or burned in. To do this you simply place the test strip over the area and make the test exposure. This will help you determine the time to expose this particular area of the negative. As an example, you have found from previous tests that a 10-second exposure produces the best overall print. However, the shadows appear too dark, so you place a test strip over the image of the shadow area. You know that a 10-second exposure is too long for this area, so you try a reduced printing time. Naturally, the exact time to use must be determined by testing. This use of test strips will greatly reduce the waste of valuable printing paper.

Exercises (263):

1. How can you make local exposure changes during projection printing?

2. What must you do to make sure there's no evidence of local exposure control on the prints?

264. Indicate the best distortion control method for given hypothetical projection printing situations.

Distortion Control. Perspective is defined as the representation on a flat surface of natural objects as they appear to the eye. Occasionally you will notice in viewing a print that the objects photographed look unnatural to your eye, not at all the way you think they should appear. Nearby objects look much larger than they should in relation to the background objects. What causes this unnatural effect, or distorted perspective? This effect is due to the fact that objects which are close to the camera lens appear large, while objects of equal size appear smaller as the distance from the lens to the subject increases. This is also true when objects are viewed with the eye, but the brain interprets this apparent exaggeration and makes a mental correction.

Cause of exaggerated perspective. Experienced operators using the proper camera position plus special camera swings and tilt adjustments can produce a perspective that will appear natural and pleasing to the viewer of the final print. View cameras have adjustments that let us make the film nearly parallel with the subject in spite of the viewpoint, but many cameras can't correct the alignment of the film and the subject. As a result of these limitations, many negatives show noticeable convergence of lines that should not be so obviously convergent. This places the burden of correcting exaggerated perspective on you, the laboratory specialist.

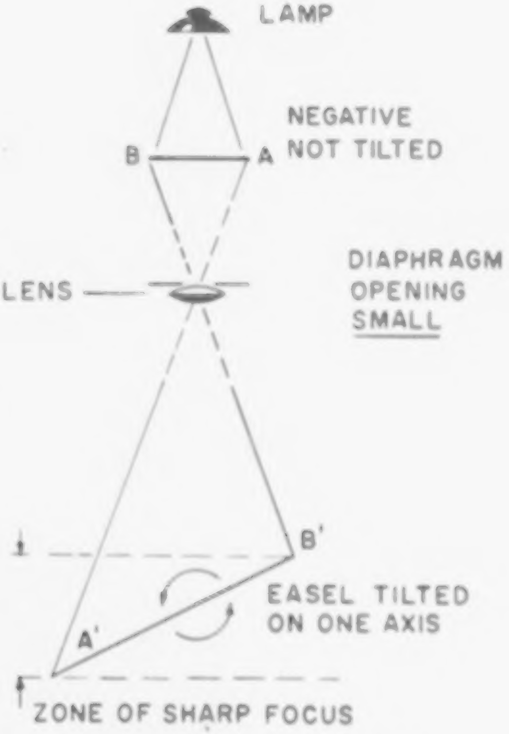


Figure 2-8. Correction by tilting the easel.

Control of exaggerated perspective. Some kinds of exaggerated perspective can be corrected by a projection printer. This control is based on the fact that the farther the easel is from the lens, the larger the image will be. Thus, if the image is projected on a tilted plane or from a tilted negative, the part of the image that's farthest from the negative will have the largest image size. Conversely, the part that's closest to the negative will have the smallest image size. If the negative consisting of parallel lines were to be projected onto a tilted plane, not all parts of the negative would be recorded as parallel. By the same token, a negative that has lines that aren't parallel (within limits) could be projected so that the print would show them as parallel. As an example, suppose you must print a photograph of a tall building and, because of a lack of controls on the camera, the photographer had to point the camera upward. As you know, this would result in an undesirable convergence of parallel lines. Simply stated, the building would appear wider at the bottom than at the top.

This can be corrected in projection printing by tilting the easel so that the image of the top part of the building is farther from the printer lens, as shown in figure 2-8, thus restoring the vertical lines to their correct position. Figures 2-9 and 2-10 show a building as it would appear before correction and the effects of tilting the easel during printing. If the enlarger has a pivot that lets you tilt the head, you can get the same effect by tilting the head away from vertical and moving the easel. Figure 2-11 illustrates these two methods of adjusting the enlarger to control perspective.

Some enlargers also have a tilting negative carrier for correction of perspective. If you tilt the negative instead of the easel (fig. 2-12), the result is much the same as when the easel is tilted. Since the same negative-easel relationship exists in figure 2-8 that existed in figure 2-12, the effects on the image would be the same.

When a projection printer is used with either a tilted easel or a tilted negative carrier, you must use a very small f/stop to maintain sufficient depth of field and keep the entire image in focus. For best results, you should focus for the center part of the picture, and then stop down the diaphragm until the sides of the picture are brought into focus.

If you carefully examine figure 2-8 and 2-12, you will notice that if both the negative and easel are tilted on the same axis *but in opposite directions*, the correction will be the same. In addition, the plane of sharp focus will be parallel to the easel. Thus, the arrangement in figure 2-13 works very well to correct perspective on a single axis. Since the plane of sharp focus coincides with the tilt of the easel, the diaphragm aperture can be relatively large.

Not many projectors have negative carriers that can be tilted, but many projector heads can be tilted. This, in effect, is the same as tilting the negative. What you must remember is—it is the negative-easel relationship that is significant.

Figure 2-9. Photograph of a building before correction.

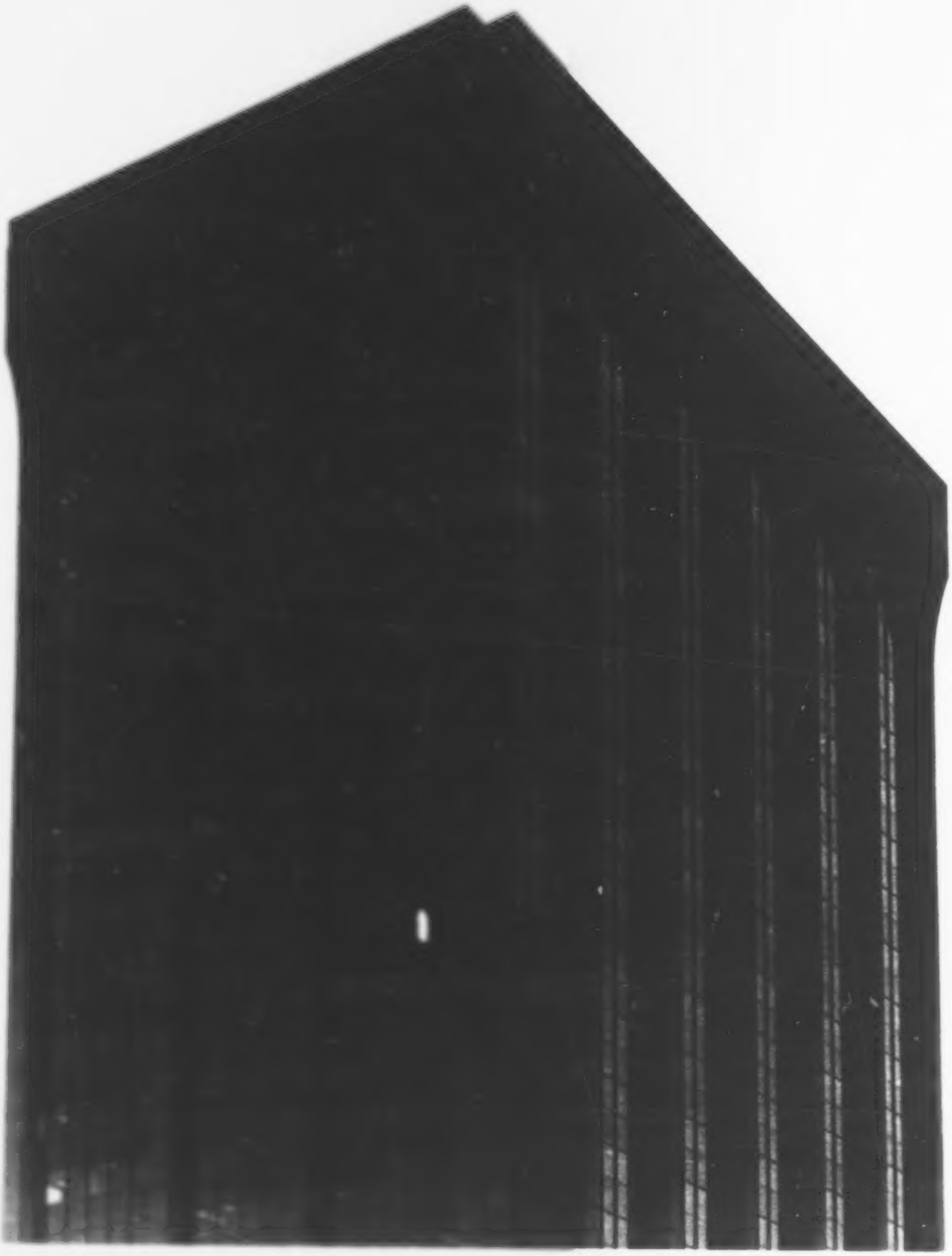


Figure 2-10. Effect of tilting easel during printing.

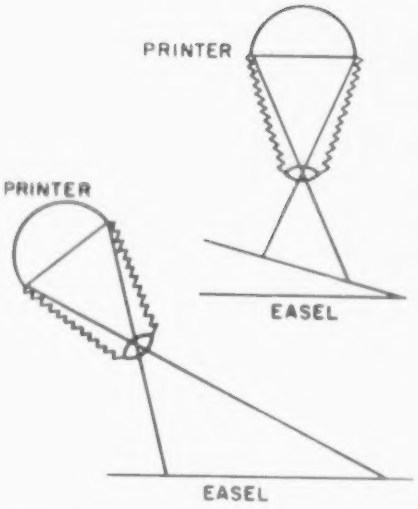

PRINTER
PRINTER
EASEL
EASEL

Figure 2-11. Two methods of adjusting enlarger to control perspective.

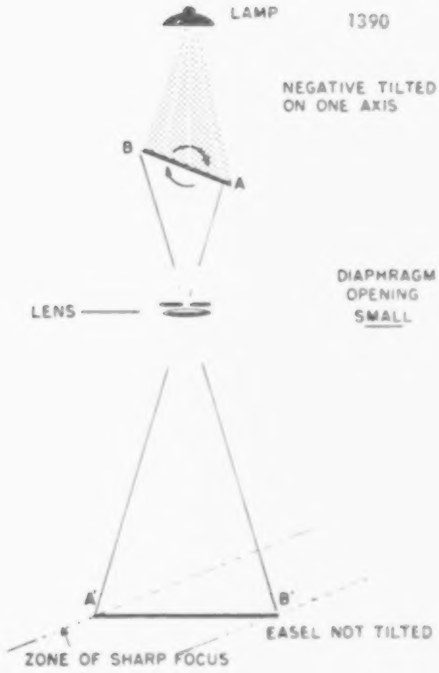

LAMP
1390
NEGATIVE TILTED ON ONE AXIS
B
A
DIAPHRAGM OPENING SMALL
LENS
A'
B'
EASEL NOT TILTED
ZONE OF SHARP FOCUS

Figure 2-12. Correction by tilting negative.

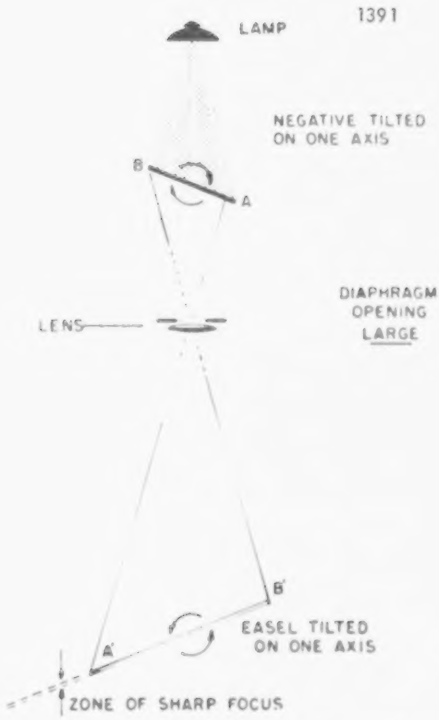

LAMP
1391
NEGATIVE TILTED ON ONE AXIS
B
A
DIAPHRAGM OPENING LARGE
LENS
B'
EASEL TILTED ON ONE AXIS
A'
ZONE OF SHARP FOCUS

Figure 2-13. Correction by tilting both negative and easel.

Exercises (264):

How would you do each of these during printing?

1. Correct a portrait of a seated person whose knees are much larger than the head.

2. On a ground-level photograph of railroad tracks, exaggerate the converging of the tracks.

3. In a photograph of a tall building, correct the perspective.

4. In a photograph of a building, increase the depth.

2-7. Manual Film Processing

The first and most important rule of manual film processing is that you keep everything spotlessly clean. The smallest speck of dust on a piece of equipment has an annoying way of being attracted to the most important negative, the one that cannot be replaced, and usually the one with the most information. Follow the rules strictly. Use a thermometer and be sure it is an accurate one. If the instructions say, "Develop 6 minutes at 68°F," be very sure that the developer is at this temperature; then be sure the developing time is exactly 6 minutes. Use a clock or photographic timer that rings a bell or sounds a buzzer when a previously set time has expired.

265. Cite the recommended developing procedures for different type films.

Developing Methods. Sheet film, because of its stiffness, can be developed one sheet at a time in a tray or in groups using various kinds of sheet-film tanks. Tray development is used mainly with the slower films, particularly the blue-sensitive process film types or the slow ortho films, which can be developed by inspection. One or two panchromatic films needed in an emergency may be tray-developed, but since this must be done in total darkness, the film may become scratched.

Tanks for sheet film are never daylight loading, but some are designed so that development can be done in room light after loading the films in the dark. A Nikor rack is available for smaller sheet film and fits the usual metal canister used with the rollfilm reels. Larger sizes of sheet film are developed best in hangers—simple metal frames suspended from crossbars, each holding a single sheet of film. After you slide a sheet of film into the grooves of each hanger and latch the top, you suspend the hangers as a group in the tank.

Various kinds and sizes of tanks are available. For sizes up to 4 inches x 5 inches, there are simple plastic and metal tanks. Some are just metal boxes and are intended for loading in total darkness; others have an inside shelf on which the crossbar of the hanger rests. In all cases the entire tank is covered with a lighttight lid, permitting development to proceed in full room light.

Larger films (5 x 7 and 8 x 10) use simple open tanks. Although these can be made of hard rubber, most photographic facilities now use stainless steel tanks. Larger units usually consist of two or more insert tanks and a surrounding water jacket, which maintains the temperature of the solutions. The space in the water jacket between the two tanks is for washing the films so that the circulating cooling water is not wasted. This has an additional advantage: since developer, hypo, and wash are all at the same temperature, this eliminates the danger of recirculation.

Where the standard 3½-gallon, 8 x 10-inch sheet film tank is used, a convenient accessory is the developing hanger rack, which provides a support for loaded hangers. When all hangers are loaded and placed in the rack, the entire rack is lifted and placed in the tank. During processing, the rack is transferred from the developer, to rinse, to hypo, and to final wash without anyone having to handle the hangers.

Exercises (265):

1. To what film size or sizes does each statement apply?

   (1) Tanks for this film are never daylight loading.

   (2) This size film may be tank-developed in room light.

   (3) Only open-type tanks are available for this film.

   (4) The hangers for this size film may be placed in a hanger rack to facilitate processing.

266. Distinguish among agitation procedures by their negative characteristics, and state the cause of developing steaks.

Principles of Agitation. When you place exposed photographic materials in a developer solution and let them develop without any movement, the action soon slows down because the developing power of the solution in the emulsion and in contact with its surface becomes exhausted. If you agitate the material, though, fresh solution is continually being brought to the emulsion surface and the rate of development remains constant.

To appreciate fully the influence of agitation on the progress of development, you must recall what you learned about the development process itself. As the developing solution reduces the exposed silver halide grains in the emulsion gelatin to metallic silver, it produces a number of oxidation products and other by-products that tend to slow down the progress of development. In stagnant development, some parts of the solution are richer in by-products than others, because more development takes place at high-exposure regions.

For this reason also, development is slowed much more at regions of high exposure than at those of low exposure, with a consequent decrease in negative contrast. This is shown in figures 2-14, 2-15, and 2-16. The negative for figure 2-13 was developed without agitation; the negative for figure 2-14 got occasional agitation; and the one for figure 2-15 got continual agitation during development. The contrast difference among the three images displays the effect of agitation upon image contrasts. Figure 2-17 shows characteristic curves plotted from sensitometric strips that received equal exposure and development, but different degrees of agitation (like these three negatives).

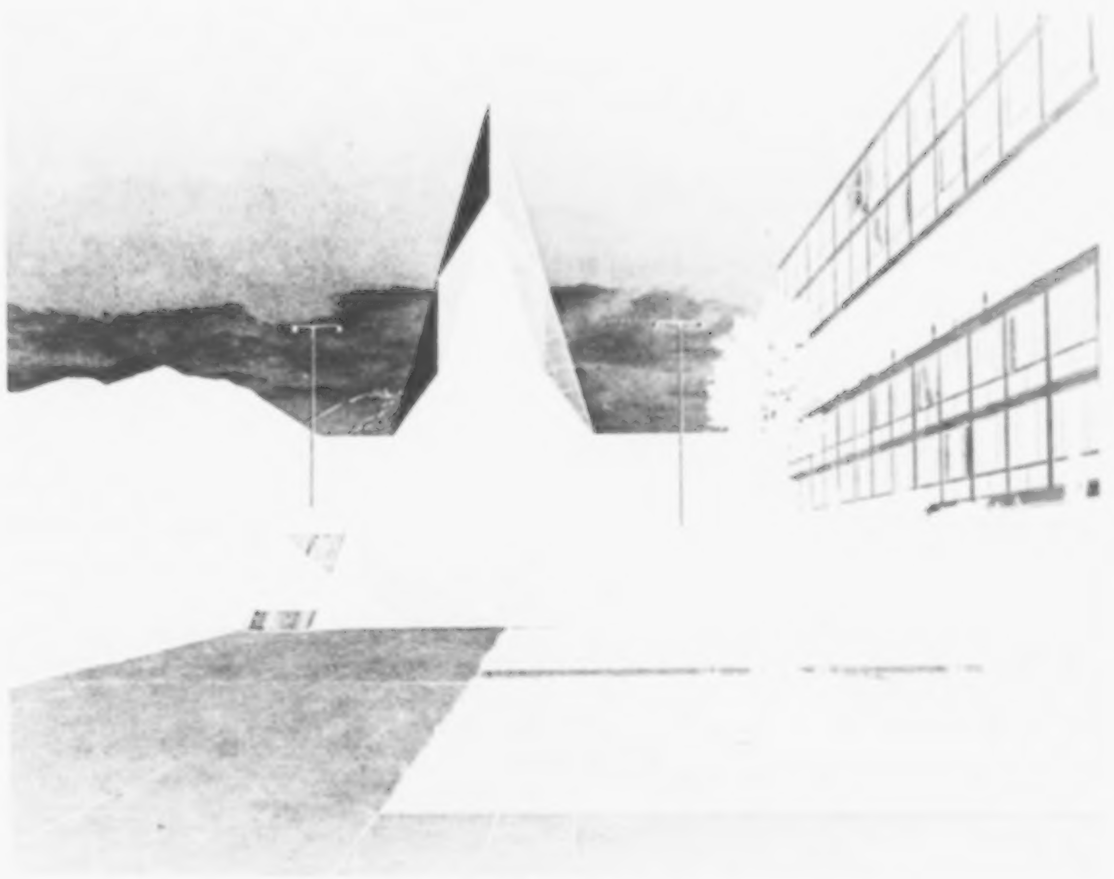


Figure 2-14. Negative without agitation.

Remember, the reason you follow a regular system of agitation is to get adequate and identical development over the entire surface of the emulsion. When you use tray or tank processing, you may be developing films, paper, or glass plates. Processing of these materials may be extremely critical.

Agitation has an important effect on the degree of development you get. An even more important effect is prevention of uneven development, or mottle. As we've said before, if there is no agitation, the exhausted solution, loaded with by-products, may flow slowly across the emulsion from the dense areas and produce uneven streaks. Next we'll look closer at some of the ways to agitate solutions, including motion of the solution container, a stream of compressed inert gas or air bubbles, and circulation system by jets.

Exercises (266):

1. State which agitation method (continuous, intermittent, or none) was probably used to develop a negative that has:
   a. High density and contrast.

   b. Low density and contrast.

   c. Medium density and contrast.

   d. Medium density and high contrast.

2. Developing streaks can be attributed to what factor?

267. State the negative characteristics that would appear if given agitation methods were not followed.

Agitation by Motion. This agitation uses either manual or mechanical rocking of the solution container. Small trays or containers are usually hand-rocked, while larger trays and tanks generally are agitated by mechanical rocking devices. Hand-rocking gives very satisfactory results if it's done right. With mechanical devices, the timing of the movement is controlled automatically by a suitable gear arrangement. In agitation by motion, and especially with mechanical rocking devices, there is danger of uneven development because of standing waves in the currents set up by the movement of the tray or tank.

Mechanical rocking devices often increase the formation of these standing waves because their motion is too regular in certain preferred directions. Naturally, uneven development may also occur in hand-rocking systems. In instances where the tray is tipped only in two directions, standing waves form in the center of the tray. With any system you must fasten the films down some way to keep them from covering one another and to insure even development. One system recommended of rocking a tray by hand consists of lifting each of the four tray corners to an angle of 40° at such a rate that you make three complete cycles each minute. Another system specifies rocking the tray 35 times per minute.

Agitation by Compressed Gas or Air. Compressed nitrogen gas is usually used for agitation during development. Compressed air is used for all other steps, where oxidation of the processing solutions is not a problem. A typical arrangement for a deep tank processing unit is shown in figure 2-18A, and B. The compressed gas is released from a multipronged plenum at the bottom of the tank. The gas comes in bursts lasting about 1 to 2 seconds, repeated every 10 to 30 seconds. The gas bubbles rise to the top of the liquid and vigorously displace the solution at the film surfaces, providing good agitation. Since the gas is released in discrete bursts, the upward movement is random instead of in a closed pattern as it would be if the gas were released continuously.

The availability of compressed nitrogen gas in a variety of cylinder sizes to fit different rates of use levels is another factor that has aided the widespread use of this system of agitation. Of course, the rate of use is minimized by using short gas bursts instead of a continuous gas stream.

Any processing system that uses both nitrogen gas and compressed air for agitation is of special concern. You must take care to insure that you use the right gas cylinders to replace those expended through use. The cost of the operation will be increased if you use nitrogen for agitation instead of air, and, if you use air instead of nitrogen, the product and solutions will be degraded, if not completely ruined. This latter mistake accelerates developer oxidation, causes decreased product density and contrast, and produces emulsion stains.

Agitation by Circulation Systems and Jets. By circulating the developing solution during processing, we

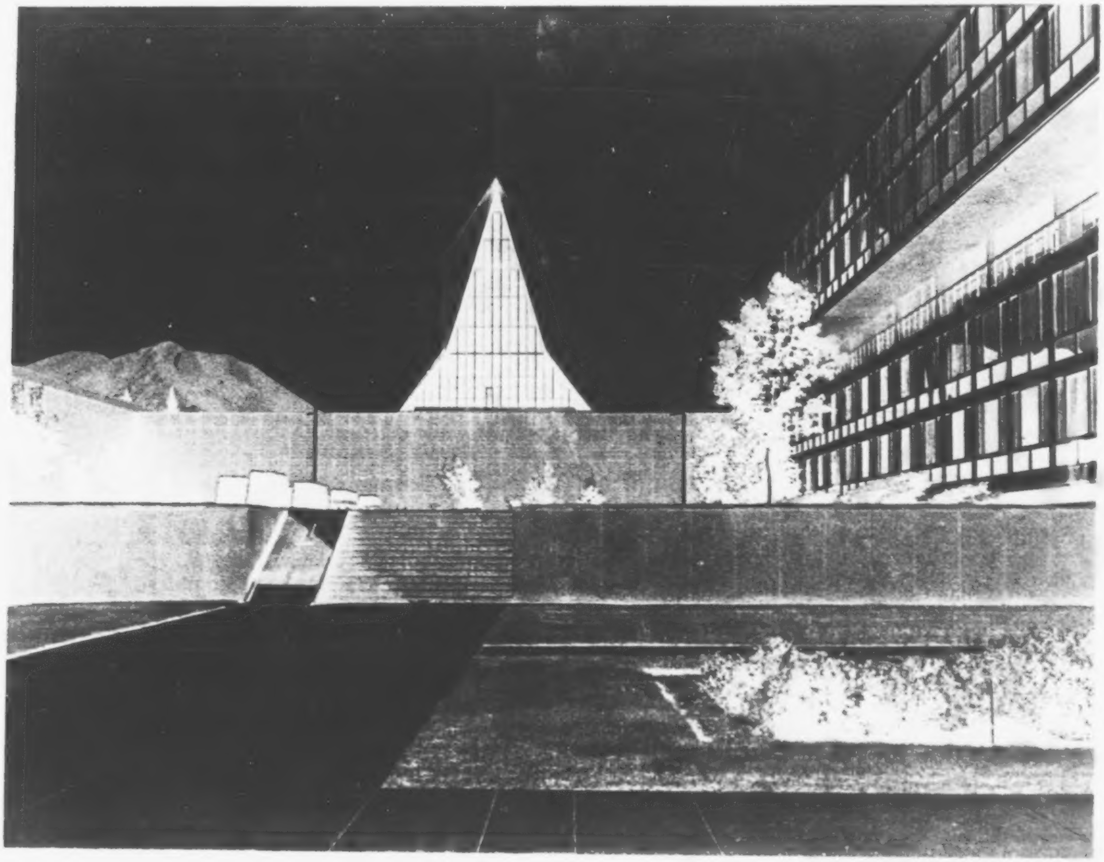


Figure 2-15. Negative agitated once a minute throughout the developing period.

186

Figure 2-16. Negative agitated constantly throughout the developing period.

do two things at the same time. First, we agitate the developer, and, secondly, we control the temperature of the solution by circulating it through a heat exchanger.

This system of agitation is used in many branches of photographic work where large volumes of solution are handled. The circulation comes from pumps, which usually circulate the developer through a feed and storage tank as well as through the developer tank itself. Since the rate of developer circulation is rather low, the agitation given by the moving liquid is not enough for critical work. It is preferable to provide more vigorous developer agitation by spray jets submerged in the solution tank. If the pressure of the pumping systems is great enough, the developer can be sprayed against the film emulsion.

Some recent spray processors spray the processing solutions with a great deal of force onto the emulsion. This spraying is done in a sealed inclosure that is not filled with the processing solution. Instead, the solution drains from the film and is collected in a sump to be discarded or to be replenished and reused. Aerial oxidation is a problem in such a system, as is uniform development, but with proper nozzle design, you can get uniform agitation.

7544

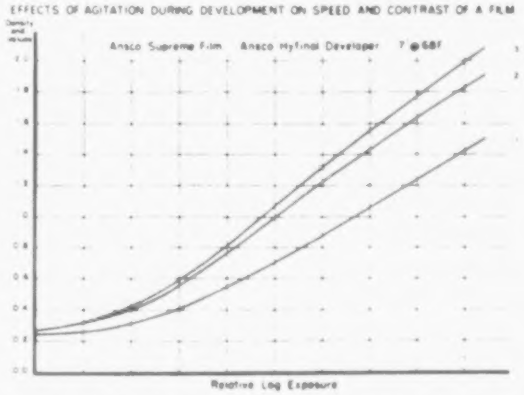


Figure 2-17. Effects of agitation during developing on speed and contrast of a film.

Exercises (267):

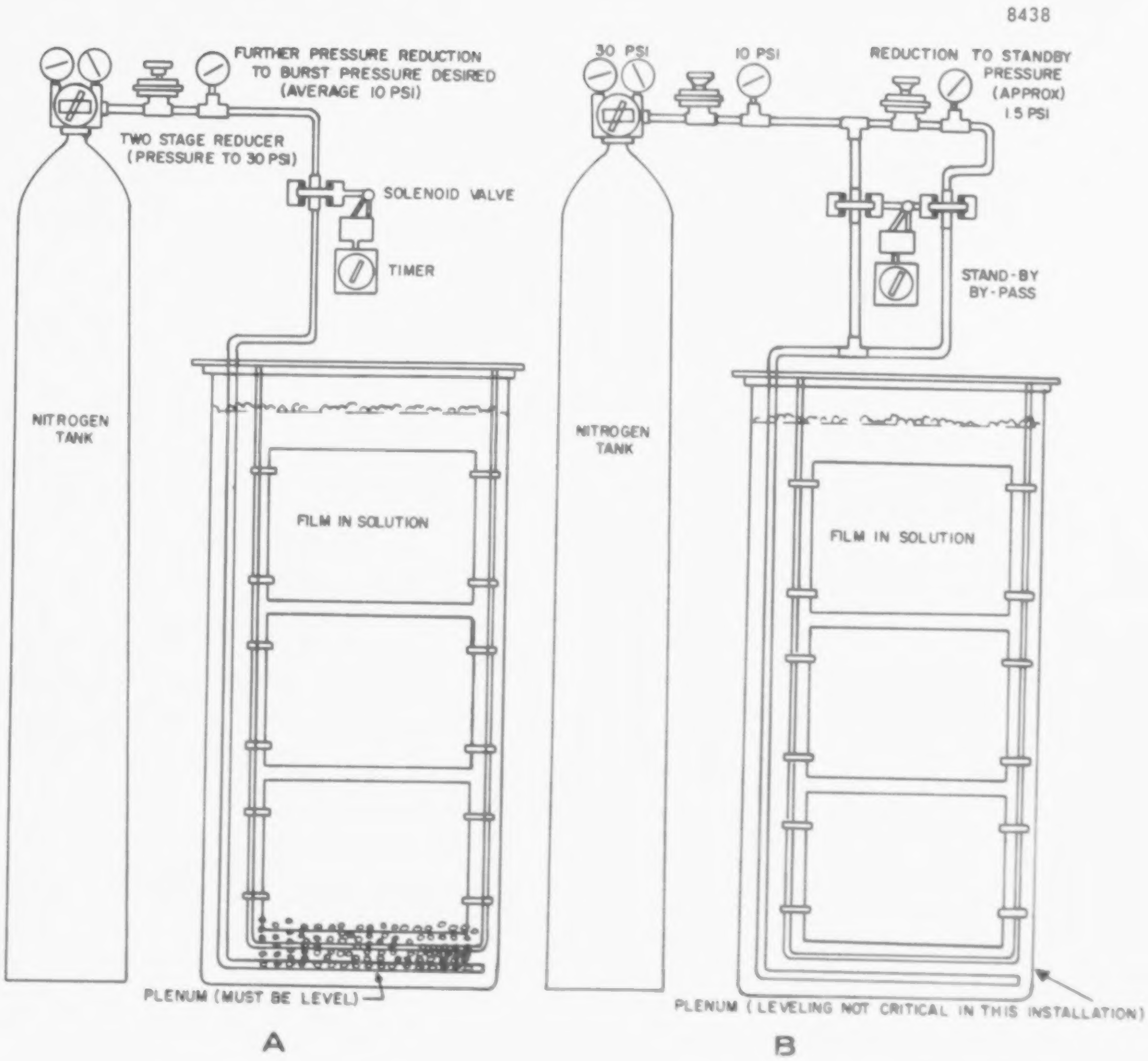
1. What is always a danger when you agitate by rocking the solution container?

2. What undesirable characteristics would be produced in the negative if you used air for agitation instead of nitrogen?

3. What spray agitation problems are alleviated by proper nozzle design?

2-8. Film Washing

To get permanence in photographic films and papers, we must take more care than is necessary for routine photography. At this time, let's discuss how archival quality is obtained.


8438
FURTHER PRESSURE REDUCTION TO BURST PRESSURE DESIRED (AVERAGE 10 PSI)
TWO STAGE REDUCER (PRESSURE TO 30 PSI)
SOLENOID VALVE
TIMER
NITROGEN TANK
FILM IN SOLUTION
PLENUM (MUST BE LEVEL)
A
30 PSI
10 PSI
REDUCTION TO STANDBY PRESSURE (APPROX) 1.5 PSI
STAND-BY BY-PASS
NITROGEN TANK
FILM IN SOLUTION
PLENUM (LEVELING NOT CRITICAL IN THIS INSTALLATION)
B

A Single solenoid burst system

B Standby pressure system

Figure 2-18. Deep tank processing.

268. State what we mean by archival quality and what steps must be precisely controlled to get it.

Archival Photographic Quality. What does "archival quality" mean? In photography it means the *keeping properties* of the final photographic product, not for days or weeks but for many, many years. If a photographic material has been processed for archival quality, this means it will not deteriorate with the passing of the years. Anything that may lead to or prevent eventual deterioration of the photographic image must be considered carefully. Only in this way can we produce materials with the best keeping quality obtainable. We must consider such things as the composition of the stop bath, the fixing bath, and the wash.

Exercises (268):

1. What is archival quality?

2. What factors must be precisely controlled for archival quality?

269. State the ideal factors of stop baths and fixing baths for archival quality negatives.

Stop Bath. The pH of the stop bath has an indirect controlling effect on the archival quality of the photographic materials. For best results, the acetic acid stop bath should be between a pH of four and six—low enough to react with the alkali of the developer and high enough not to damage the emulsion. The acid used in the stop bath should be weak so that its reaction with the alkali will be slow. Very strong acids diluted to the right pH don't have the best archival effects. Since acetic acid meets the requirements, it is normally used in stop baths for archival quality.

Fixing Bath. The freshness of a fixing bath is another factor in the keeping qualities of the final product. As a fixing bath approaches exhaustion, the tetrathionates formed become increasingly difficult to wash from the emulsion. When the archival quality of specific pieces of material is of utmost importance, frequent controlled checks of the fixing bath are essential, especially if the processing is done with equipment that uses fixing bath recirculation, silver recovery, and fixing bath replenishment. A double fixing bath arrangement is desirable for archival quality when you process in trays. Use a partially used fixing bath, as the first bath and place a fresh fixing bath in the second bath. At frequent intervals as the first bath approaches exhaustion, discard it. Place the used second bath in the first position and a fresh fixing bath in the second position. This assures thorough fixation of the sensitized material.

Exercises (269):

1. What characteristics of a stop bath enhance archival quality?

2. Why must fixing baths be fresh for archival quality?

270. State how given washing conditions will affect the removal of thiosulfates from the emulsion.

Wash. An unwashed or improperly washed emulsion will stain, crystallize, and fade, so washing is just as important as any other part of processing. It is essential to remove as much of the complex salts and fixing agents chemicals from the emulsion as possible. Only with good washing can the image permanence be at its best. Don't forget that the primary purpose of the fixing bath is to convert the insoluble silver halides into water-soluble compounds. If fixing is incomplete, no amount of washing can possibly render the image permanent. This is an important fact to remember.

As the washing time increases, the amount of hypo diffusing out of the emulsion decreases. In other words, the quantity of fixing by-products leaving the processed sensitized material at any moment is proportional to the quantity present at that time. After 1 minute, approximately one-half of the by-products will be removed. After the second minute, about one-fourth of the original amount will have been removed, and one-fourth will remain. By the time 20 minutes have passed in the wash (with effective washing), only about one-millionth of the amount originally present in the emulsion will remain. Washing time of the emulsion depends on (1) efficiency of the washing system, (2) chemical composition of the fixing bath, (3) temperature of the wash water, (4) pH of the wash water, (5) amount of hypo in the emulsion, and (6) degree of hypo removal required.

Other conditions remaining constant, the faster the water in contact with the emulsion changes, the less washing time is required. Materials processed in nonhardening, or chrome alum, fixing solutions wash faster than materials processed potassium alum baths. Washing time varies with the pH of the fixing bath when potassium alum is used, being more rapid at pH values above 4.9. Washing is faster when the material has been fixed in a fresh fixing bath than when it is fixed in a partially exhausted bath.

Properly hardened films and plates wash more rapidly in warm (75°F) water than in cold (65°F) water. When negatives have not been properly hardened, they require a longer washing time, due to the increased amount of fixer and by-products in the swollen gelatin. Increasing the pH of the wash water from 7 to 11 (by the controlled addition of ammonia) increases the rate of washing.

Negative emulsions need longer washing times than positive emulsions (on the same base material) due to the thicker emulsion. Paper takes much longer washing periods than films or glass plates, because it absorbs more fixing solution.

It is not always essential that the maximum amount of hypo be removed from the emulsion. Permissible concentration of hypo for ordinary work varies from 0.02 to 0.4 milligrams per square inch, but true archival quality limits residual hypo to 0.005 milligrams per square inch. Wash time is not affected to any appreciable degree by how long the material stays in the fixing bath (as long as it is at least twice the clearing time), acid stop baths and hardening stop baths, concentration of silver halide solvent in the fixing bath, or composition of the developing solution.

Impure wash water may leave spots of precipitate on the material and affect archival quality. You need an adequate flow of reasonably pure water for long enough to get archival quality. Since we have already seen that the removal of hypo is exponential, there will always be some hypo in the emulsion no matter how long it is washed. Hence, we must work within tolerable limits. When the residual hypo has been reduced to 0.005 milligrams per square inch (or less), it will never damage the image. But how can we be sure that the concentration does not exceed this amount? The procedures are covered in the *American Standard Method for Determining Residual Thiosulfate and Tetathionate in Processed Photographic Papers, Z38.8.25–1950*, and in *American Standard for Determining the Triosulfate Content of Processed Black-and-White Photographic Film and Plates, PH4.8–1958*. While it is not practicable to spell out the detailed procedures here, you should understand the basic principles.

In determining the amount of residual hypo in films, the test sample is placed in a specific volume of a specially prepared test solution, where it causes turbidity in proportion to the amount of hypo present. You then compare this resultant turbidity to a series of specially prepared standard turbidities. The amount of residual hypo in the film is determined from the tables that are used in the preparation of the standard turbidities. The hypo concentration is comparable to that of the standard which it matches most closely.

Composition of the wash. While the purity of wash water is not as critical as the purity of the water in the processing solutions, it is nonetheless an important factor. Water from the same supply used for human consumption is normally pure enough for washing photographic materials.

Sea water may be used for washing photographic materials; in fact, the salt in sea water actually helps remove hypo, but materials washed in sea water must be rewashed in fresh water long enough to remove the undesirable chemicals of the sea water.

It is important that the wash water used for film and paper be reasonably free of chemicals or contaminants. If large amounts of sensitized materials are being processed, you should run a periodic check on the photographic chemical content of the wash water to make sure it is not contaminated.

Available wash water may be contaminated with vegetable or animal matter; dissolved salts such as bicarbonates, chlorides, and sulfates of calcium, magnesium, sodium, and potassium; grit; or other matter. Almost any water can be purified to meet photographic washing requirements, but the method of purification depends on the type and amount of contaminants.

Analysis of the Wash. Your main reason for analyzing the wash water is to assure image permanence. It is impossible to wash the fixing bath and by-products of fixation from the emulsion of sensitized materials if the wash water itself is laden with these very chemicals. Way to check the wash water is to measure the pH of clean unused water (from the same source as the wash water), check the pH of the wash water in contact with the material as it leaves the wash tank, and then compare the two pH readings. If the readings compare favorably, it indicates that the washing is effective. Another way is to prepare and use a hypo test solution or use a commercially prepared test solution). Although extremely small quantities of hypo are hard to detect, a good hypo test solution will tell you if the hypo has been removed satisfactorily. One such hypo test uses an indicating solution of water, potassium permanganate, and sodium hydroxide. This solution will change color when an excessive amount of hypo is dripped into it from the material being washed.

Photographic data books such as the Kodak Data Book, *Processing Chemicals and Formulas for Black-and-White Photography* or the *Photo-Lab-Index*, published by Morgan and Morgan, contain formulas for preparing hypo test solutions. You should refer to these or similar publications for the latest developments in preparing and using the test solutions.

Exercises (270):

1. Match the list of photographic material washing conditions in column A to the probable effect the conditions in column B will have on the material.

Column A	*Column B*
____ (1) Wash water flow rate is extremely slow.	a. This condition will enhance the removal of thiosuofates.
____ (2) Wash water temperature is 75°F.	b. Washing time must be increased.
____ (3) The only large quantities of water available for washing film is sea water.	c. This condition will result in faster washing.
____ (4) The fixer solution contained potassium alum.	
____ (5) pH of the wash water is 6.8.	

2-9. Material Drying

Film drying is not the simple, uncomplicated thing it seems at first glance. It involves a combination of variables, most of which can be satisfactorily controlled. To make sure that you thoroughly understand this drying process, let's discuss the image formed in the gelatin emulsion. In the first place, the gelatin itself has certain peculiar properties.

271. List the factors that determine how much water gelatin absorbs.

Gelatin. After being extracted from animal issue, gelatin is a rather thick liquid which, as it loses moisture, changes first to a moist jellylike substance called a *gel* and then to a dry solid. It is *hydrophilic*, meaning that it has a strong affinity for water and will absorb it readily, changing from a solid back to a gel. Upon drying, the gel once more becomes a solid.

The temperature and the pH of the water largely determine how much water gelatin can absorb. The higher the temperature, the more the gelatin will soften and swell. If there's enough water and the temperature is high enough, the gelatin may pass through all three physical states, from solid to gel to sol (liquid). Obviously, you normally won't want your emulsion to pass through this last change.

The effect of pH on the emulsion is more complicated. At about 4.8 pH, gelatin expands very little, but as the pH increases or decreases, the rate of swelling increases. Thus, gelatin swells extensively in solutions that are either above or below 4.8 pH. As a result, the pH of the wash water will have some effect on the state of the gelatin, how much water it holds, and how fast the water will diffuse out during drying.

Exercises (271):

1. What two factors determine how much water is absorbed by gelatin?

2. The absorption of water by gelatin is least at what pH?

272. State how the photographic image influences the absorption of water by the emulsion.

Image. The photographic emulsion, as you know, consists of one or more layers of gelatin with silver halides of varying sizes distributed through the layers. After exposure and development, halides are changed to silver metal, which occupies space and does not absorb water. In an unexposed emulsion, the undeveloped silver salts are made soluble and are removed from the emulsion during the fixing and washing stages. Only the gelatin and the space occupied by the halides remain, and these do absorb water. Because of these conditions, dense negatives or negatives with many heavily exposed areas hold less water and dry faster than thin negatives or negatives with many lightly exposed areas. If you think about this for a moment, you will see that, since the heavily exposed and lightly exposed areas are distributed randomly throughout the average negative, drying is rapid in the dense areas, slower in the intermediate areas and the thin or unexposed areas. Obviously, then, negatives do not dry uniformly.

Exercises (272):

1. Which of the two listed conditions in each problem would result in the greatest absorption of water by the negative image?

   a. In a copy negative of a black-and-white line drawing, the area of the negative that represents the lines or the background of the original.

   b. In an aerial negative, the areas that represent foliage or the areas that represent cultivated fields.

   c. In a woman's portrait, the lips or the cheeks.

   d. In any unfogged negative, the edges of the negative or the negative image areas.

273. State the drying action that takes place in hypothetical work situations.

Drying Action. When gelatin dries, the water it holds must first migrate to the surface and then evaporate into the air. Ideally these processes should take place simultaneously and at the same rate, but if the surface moisture does not evaporate, the moisture in the gelatin can't diffuse out. Furthermore, if the surface moisture evaporates too fast, the surface gets hard, and the internal moisture can't migrate out through it. In addition, if drying is too fast, the outer surface shrinks while the rest of the gelatin layer is expanded. This causes strains that can harm the emulsion.

For a negative to dry, it must be surrounded by dry air—air that has a lower relative percentage of moisture than the gelatin. Heating air causes it to accept more moisture, but if the air does not move, even heated air can rapidly reach a state of equilibrium with the moist film, and drying will stop. Moving the damp air away from the surface of the wet film and replacing it with dry air will let drying continue. This is the air impingement principle of dryers currently in use.

Air Impingement System. In an air impingement drying system, air is warmed and blown against (impinges upon) the surface of the wet film. The warm, dry air picks up moisture and moves on. It is immediately replaced by more warm, dry air, and the process continues until the film is dry. The rate of drying is controlled by adjusting the velocity, temperature, and humidity of the air in the drying chamber. In very hot and humid climates, where the air is saturated with moisture, the air must be passed through a dehumidifier before it enters the drying chamber. If this is not done, the film will not dry. In very dry climates you must reduce both the heat and the air velocity to prevent overdrying.

Drying Progression. Photographic films and plates begin drying at the corners and edges as well as in the areas of heaviest density, and strains in the direction of the dry areas are introduced. Glass supports resist these strains to a great degree; but film supports, being flexible, curl toward the dry areas. As a film continues to dry, the strains gradually being to equalize; and the film if properly dried, will ultimately lie flat. The surface will not be moist to the touch but will be firm; yet it will be soft enough that flexing will not damage it. If it's overdried, the film will curl toward the emulsion and tend to be brittle. The rate of drying and the amount of curl also depend on how thick the emulsion layer is and whether or not the film has a gelatin backing. Naturally, the thicker the layer, the longer the drying time. A gelatin backing takes time to dry, but it introduces an opposing curl and causes the dried negative to lie quite flat.

Water Spots. One of the main sources of trouble in drying negatives is the formation of water droplets (teardrops) on the surface of the emulsion. The film will dry and contract at its normal rate in the areas around the drop of water while the area under the drop is still expanded. This sets up internal strains in the gelatin so great that the emulsion is irreparably damaged. The water spot produces an apparent increase in density, because the strained emulsion refracts the light so that the printing density is increased. The effect is permanent; resoaking and redrying won't repair this damage. The best way to avoid the effects of water drops is to keep them from forming. You can immerse film in a wetting agent (such as Aerosol or Photo Flo) after washing to break down the surface tension of the water so that it won't form into drops. Also you can wipe the surface gently with a clean, damp chamois skin, a fine cellulose sponge, or an appropriate squeegee to remove water drops.

Exercises (273):

1. Why will film not dry when the relative humidity of the surrounding air is 100 percent?

2. When there's no evaporation, what other drying action stops?

3. The temperature of an impingement-type dryer is increased to 160°F (125°F is recommended). Which of these will happen?

   a. The film will dry evenly.

   b. Emulsion ruptures may occur.

   c. High-density areas will dry faster than low-density areas.

   d. Diffusion and evaporation will occur at a faster, but even, rate.

   e. The surface may become dry, shrink, and entrap the remaining moisture within the emulsion.

2-10. Printing Processing Solutions

A developer formula is designed for one thing—to reduce exposed silver halides to metallic silver. It makes no difference if the silver halides are in emulsion coated on film support, paper support, or glass support; the objective is still the same. Many chemicals can provide the photographic results we want, but, only a few combinations of chemicals yield results we want, but only a few combinations of chemicals yield the nearest thing to the ideal developer that has been designed. Let's discuss one of these combinations as it applies to printing processing.

274. Given a standard chemical formula, state the effect on photographic materials when the quantities of certain components are altered.

Developer Composition. In selecting a standard developer for print processing, the ideal choice is one that develops the exposed silver halides fully and quickly. Such a developer is Armed Forces Developer Number 25. As we've said over and over, the objective of a developer solution is to reduce the exposed silver halides to metallic silver. Table 2-1, gives the formulas for Armed Forces Developer 25 and two other film developers. Notice that the same chemicals are used for all formulas. The only difference is in the quantity of each component.

Each component serves a particular function within a developer solution, and normally the higher the concentration of the component, the more dramatic its effect. As an example, in the formulas listed in table 2-1, sodium carbonate is used as the accelerator. As the quantity of this chemical increases, the activity of the developing agents also increases. This principle holds true for any other component.

Exercises (274):

Refer to table 2-1 to answer these questions. If you can't answer from this objective segment, review Section 2-1 of this volume.

1. If the quantity of potassium bromide used in developer number 1 was used in number 25, what effect would it have on the solution?

TABLE 2-1

STANDARD DEVELOPER FORMULAS

	#25	#1	#2
Water (125°F)	24 oz.	16 oz.	24 oz.
Metol	44 gr.	27.4 gr.	15 gr.
Sodium Sulfite (anhydrous)	1.5 oz.	3 oz.	5/6 oz.
Hydroquinone	3/8 oz. and 11 gr.	1/4 oz. and 7.5 gr.	29 gr.
Sodium Carbonate (monohydrated)	2.5 oz. and 77 gr.	13/4 oz.	43 gr.
Potassium Bromide	27.4 gr.	72.9 gr.	7 gr.
Cold water to make	32 oz.	32 oz.	32 oz.

2. If the sodium carbonate content in developer number 25 is increased, what effect would it have on:

   a. Solution pH?

   b. The activity of the developing agents?

   c. Effect of the restrainer?

275. Given a list of undesirable print characteristics, state what processing variable caused each characteristic.

Print Characteristics. As the developer is used, its chemical composition changes, and the restrainer in the film developer normally increases. This is *not* the case when you're developing paper-base prints, so you must include restrainer in the replenisher. Otherwise, the accelerator will soon be allowed to function unchecked and chemical fog will result. In this instance, the development by-products *do not* contain restraining-type chemicals as do the by-products produced during film developing. Therefore, all developer components decrease in quantity as the developer is used.

One factor that should be stressed here is that the rate of component depletion is not the same for each developing situation. The rate at which the developer is exhausted depends on how much metallic silver is produced within the image. This also holds true in processing film. In other words, the developer will not last as long in you're developing prints or scenes with a lot of foliage as it will when you're printing black-and-white line drawings.

Exercises (275):

1. You are making 50 prints of one negative and are batch-developing them five prints at a time for exactly 1 minute 15 seconds. Why does the density of each batch get progressively lighter?

2. An experimental developer can be used for both film and paper processing. The replenisher for this developer is formulated for film processing, but you use both the developer and replenisher to process a large quantity of prints. Soon there's a chemical fog on the prints. Why does this fog appear, and what can you do about it?

2-11. Print Washing

Print finishing includes all treatments given to prints from the time they are removed from the fixing bath to their final delivery. These treatments include other steps, but we will only discuss washing and drying in this CDC.

276. State the reason for print washing and the factors that affect the results.

Washing Purpose. Prints are washed after fixation to remove as much of the residual chemicals as possible. This is important, since the chemicals that remain will cause the image to fade. Fading appears in prints as a general yellowing of the photographs or as staining or bleaching of the highlights. These changes are more likely if the storage has been under high-temperature and high-humidity conditions.

Exercises (276):

1. Why is print washing necessary?

2. What change might occur in prints that have not been properly washed?

3. What environmental factors influence this change?

277. Name and state how specific factors influence print washing times.

Washing Time Factors. There are several factors which determine the rate of print fading. Within limits, the rate of print fading is roughly proportional to the amount of fixer present. This amount may be very small indeed. For instance, a concentration as low as 0.005 milligrams per square inch may, under certain conditions, cause print fading. Also the higher the humidity and temperature, the faster fading will occur.

To remove all residual chemicals from the prints and thus insure permanency, washing must be adequate. Washing dissolves and dilutes the soluble products and eliminates them with the disposal of the wash water. Although chemicals diffuse from both the base and the emulsion diffuse from both the base and the emulsion of prints during washing, it is necessary to wash prints longer than negatives. Prints should be washed longer than negatives because the fibers of the paper retain the absorbed chemicals. The allowable temperature range of the wash water for prints is from 60° to 70°F. Lower temperatures retard the diffusion of chemicals from the prints, and higher temperatures may cause the emulsion to sell and break loose from the paper base (frill).

The length of time necessary to wash prints depends upon the amount of agitation they receive in the wash, the completeness and rate the water is changed, and whether the prints are on single- or double-weight paper. A certain amount of soaking is necessary in the wash. Thus, a very rapid renewal of fresh water does not speed up the washing process. Thorough washing is also dependent upon the time allowed for the diffusion of the chemicals from the paper. Furthermore, as the quantity of the chemicals to be removed becomes less, the rate of elimination is decreased. If the prints collect into groups during washing, diffusion of the chemicals is hindered. While it is most important to remove hypo from prints, it is a poor practice to wash them for a needlessly long time. Prolonged washing may cause excessive softening of the emulsion and dimensional changes in the paper. Under favorable conditions, the usual washing time for single-weight prints is 30 to 45 minutes, and 1 hour for double-weight prints.

If prints are removed from the fixing bath and added to a batch that is washing, the fixer from the added prints immediately diffuses into those in the wash. This makes it necessary for the timing of the washing period to begin anew when the last prints are added.

Exercises (277):

1. Why is it necessary to wash double-weight prints longer than single-weight prints?

2. How does agitation influence print wash times?

3. What factor determines the ideal water change rate for print washing?

278. State the types of washing methods and give specific procedures.

Washing Methods. There are two methods by which prints can be washed satisfactorily. These are in trays and by mechanical print washers.

Washing in trays. Although most prints are washed in mechanical washers, small groups may be washed by successive changes of water in a tray. Use two deep trays. The size of the trays is determined by the size and number of prints you wish to wash. Fill both trays with water and place all the prints (emulsion up) in one tray. You should separate, agitate, and then transfer the prints one at a time to the other tray. Then empty the first tray, refill it with fresh water, and repeat the procedure until the wash is completed. When using the tray method, you should agitate the prints two or three times in each change of water and change the water at 5-minute intervals until about six changes have been made for single-weight prints. Double-weight prints should have from eight to ten changes.

A second method of washing prints in a tray involves the use of a tray siphon. The siphon directs fresh water into the top of the tray and at the same time it removes the chemically contaminated water from the bottom of the tray. The tray siphon method of washing is quite efficient.

Mechanical washers. A convenient method of washing large numbers of small and medium-size prints is by the use of a mechanical washer. These washers spray fresh water onto the prints and at the same time drain off the contaminated water from the bottom. This type of washer contains a perforated drum which is revolved by a motor. The rotation, together with the spray of water, gives constant agitation to the prints. In these washers, the water is completely changed every few minutes.

Exercises (278):

1. Name three washing methods.

2. When washing in trays, how many water changes should make for single-weight prints? Double-weig prints?

2-12. Print Drying

The lack of knowledge about drying of prints can cause you to make photographic prints that are not suitable for Air Force use. Drying is a critical part of the photographic process. Drying must be done properly if your prints are to meet the desired standards. Let's go into the principles involved first.

279. State the basic principles and methods of print drying.

Print Drying Principles. The basic drying principles in Section 2-9 were built around film drying. The principles concerning the gelatin, the image, and the drying action are identical for papers. The main difference between drying film and drying paper is that the paper backing holds a great deal more moisture than the transparent backing on film does. In drying transparent materials, your main concern is to remove moisture from the emulsion. In drying papers, you are still concerned with removing the moisture from the emulsion, but you are also concerned with removing the moisture from the paper backing. Often, you will find that this is a greater problem than removing the water from the thin emulsion. The water must diffuse to the surface of the paper the same way it diffuses to the surface of the emulsion. The drying action for prints is similar to that for negatives, but the methods are both similar and dissimilar. Let's consider the common print drying methods.

Print Drying Methods. The most commonly used methods of drying prints in the Air Force are:

a. Hanging the print from clips, which are suspended from a line in the laboratory.

b. Suspending the prints in drying cabinets, where air is circulated over them.

c. Placing the prints on bobbinet cloth material suspended across horizontal wood or metal frames with the emulsion side of the prints down.

d. Running the prints through heated drum-type dryers either with the emulsion toward the drum or away from the drum.

e. Using air-impingement drying machines.

Hanging the prints on a line with clips is a relatively slow way of drying them. In addition, there is a tendency for the prints to curl. Prints to be used for controlled measurement and for the assembly of controlled mosaics should not be dried this way, since they may suffer dimensional changes.

Suspending prints in drying cabinets with air circulated over them works well for certain types of prints if the temperature and the cleanliness of the circulating air are carefully controlled. Dimensional stability depends on the way the prints are suspended and the rate at which they're dried. This type of drying is not suitable for producing prints for mosaics or for other prints that must have dimensional accuracy, but it is suitable for ordinary prints.

Drying prints on racks covered with bobbinet cloth is *the* one recommended way when dimensional accuracy is of prime importance. With the prints emulsion-down on the bobbinet, there is little danger of dust becoming inbedded in the moist emulsion, and the amount of curl is minimized because the weight of the print works against the curl tendency.

Heated drum-type dryers are the most common method of handling sheet paper. These machines are designed so that you can glaze the surface of glossy prints by feeding them into the machine with the emulsion toward the drum. You can retain the surface of matte and semimatte prints by feeding them into the machine with the emulsion side away from the drum.

Drying machines designed for aerial rollfilm materials use air impingement to dry print material in roll form. This type of drying equipment is designed for support of mass production printing and processing equipment. Air impingement dryers are incorporated directly into some processing equipment, but some of these dryers are also designed as separate units to support machines that don't have self-contained drying units.

Exercises (279):

1. What happens to the water during print drying?

2. What drying methods force print drying?

3. What makes print drying differ from film drying?

280. State the causes of print defects during the drying process.

Print Drying Problems. Some print drying problems are tied directly to specific drying methods, but other problems are common to all print drying methods. Let's look at some specific problems, their causes, and the ways you can prevent their occurrence.

Curl. As a print dries, the gelatin shrinks; and the more it shrinks, its greater the tendency to curl. The curl is actually caused by the gelatin shrinking more than the paper backing. Since there is a shrinkage differential, the two layers tend to curl toward the layer that shrinks the most—the gelatin layer. The most effective method of preventing curl is to dry the print in either an absolutely flat position or in a position that stretches the emulsion, that is, in a position that's reverse to the curl inherent in the paper. Letting the print dry that way minimizes the tendency to curl, but in extremely dry climates you may need some additional treatment to keep from losing residual moisture from the gelatin. There are commercial flattening solutions that will help the gelatin hold its moisture. One such solution can be made up of diluted glycerin (a 10 percent solution). If you soak the prints long enough for the flattening solution to saturate the emulsion and the paper thoroughly before you dry the prints, you can keep curling to a minimum.

Shrinkage. The problem of shrinkage is not important for ordinary prints, but when the prints must be used for taking measurements or for assembling into a controlled mosaic, shrinkage of the prints becomes very serious. Print shrinkage is caused by gelatin contraction and/or paper contraction. The contraction makes the print surface occupy less area than it did at the time it was exposed. Dimensional accuracy can best be achieved by drying the prints slowly and by not subjecting them to any stress before, during, or after the drying process. When they're available, use special dimensionally stable papers. One such paper is coated with a type of waterproofing that holds water absorption to a minimum. This sensitized material is designed especially for dimensional stability; and with slow drying, the exact amount of shrinkage is predictable and can be compensated for during the printing or use of the image.

Cracks. If a print's emulsion has cracks, it very often indicates that there has been rough handling of the material, either before exposure, during processing, during drying, or since drying. If the paper's emulsion has the right amount of moisture, it can take a great deal of flexing without cracking, but if the moisture content drops below normal, the gelatin gets quite brittle and may crack when it is bent. Excessive hardening of the emulsion and drying at too high a temperature may cause the gelatin to crack more easily. Cracks can result when a print straightener, which bends the print in a reverse curl around a roller, is set to bend the material too sharply.

Change in tone (plumming). When photographic papers are dried by heating, they may tend to change tone toward a colder, more purple color. The effect depends on the amount of heat used, the nature of the sensitized materials, and the tone of the image prior to drying. If it is essential to prevent plumming, commercially prepared (antiplumming) solutions can be obtained in which the prints are soaked before drying.

Changes in print appearance. When matte and semimatte papers are dried by heat, the surfaces sometimes have a higher sheen than if they are dried naturally. Starch grains are included in the emulsion to provide matting. The rising temperature of the paper causes these grains to burst. While this effect may improve the appearance of some semimette papers, it is normally considered detrimental for prints on most matte papers. Drying can often be done according to the desires of the technician; i.e., whether or not the technician prefers the sheen.

Exercises (280):

1. What print drying method would result in excessive print curl, shrinkage, emulsion cracks, plumming, and changes in surface appearance?

2. What causes print shrinkage?

3. What causes cracks in the emulsion of a print?

2-13. Examining Quality of Negatives Visually

While it's not truly scientific, visual examination can greatly improve the quality of your products. As the name implies, carefully examine your product to see whether or not it satisfies the quality requirements of the work order. Generally speaking, you should look for such things as proper density, good contrast, and various mechanical defects. The prime ability in visual examination is recognizing good and poor quality merely by looking at the product. The first consideration is to make sure you are looking at the image under conditions of normal viewing.

281. State how to check the density and contrast of a negative.

Negative Density. Holding a negative up to a dark wall may give you an indication that it is overexposed. Conversely, if you hold it up to a strong light source, it may appear to be underexposed. Thus, to establish repeatable criteria, you must use the same viewing conditions from one occasion to the next. The best viewing method uses some sort of standard viewing table. You may use a contact printer as a viewer, but be sure to use the same number of lights in every case. Another simple method of judging a negative is to look at it using light reflected from a piece of white paper. The negative should have a range of tones comparable to the original scene.

A good negative must be neither too dense nor too thin. Thin negatives produce prints that lack shadow detail, and those that are too dense are hard to print and often have too much rain, which shows up on the print. To an inexperienced person, determining what constitutes a good negative is difficult. Bracketing the exposure should produce a negative with proper density. The biggest advantage of bracketing is that you can compare the good and poor quality negatives side by side. Being a visual control at this point, quality defies a verbal description, and experience will be your best teacher. Your best guide at this time is comparison; you can't recognize fine shadings of quality unless you can compare them with a poorer quality product.

Another way to judge negative quality is to use the negative to produce a print. If you have bracketed an exposure, make one undodged print from each negative and see which print looks best. Make your choice on the basis of which print has adequate detail in both shadows and highlights, but don't try to produce detail in unimportant shadow or extreme highlight (such as ones that are specular in nature).

Negative Contrast. The difference between densities is termed "contrast." A negative with considerable difference in the density of its shadows and highlights is said to be "contrasty" or "hard," and one with little contrast is termed "flat" or "soft." A negative that has little contrast and is also fairly transparent may be termed "weak," which can also be applied to the shadow areas (of negatives) that are thin and lacking in detail.

You just read about how to judge negative density. Remember, density depends on a number of variable factors, and so does contrast. Some things that affect contrast are lighting of the original scene, individual reflectances in the original scene, type of film, and the processing of the film. The net result of all these factors appears on the negative as a number of different densities. Since we have different densities, we have contrast. An accurate representation of the subject in the negative will present these densities in about the same way as the brightnesses of the corresponding parts of the subject. If this is the case, the negative contrast is an exact reversal of the original scene contrast. This is not always desirable, because you sometimes want more contrast or less contrast. By appropriate manipulation, you can modify the original.

Visually examine both the highlights and shadows to see if they both have good detail. If detail is lacking in either, contrast is affected. This brings you back to the contrast-affecting factor of density. The latitude of most film is considerable, and you can usually get a printable negative over a wide range of exposure, but at some point of overexposure, the highlights will attain maximum density. Any additional exposure will simply produce more density (and detail) in the shadows. The net result is a decrease of contrast. An underexposure has a similar effect in reducing contrast. Both shadows and highlights gradually decrease in density until the shadows have no detail. From this point on, the highlights are further decreased in density and gradually approach transparency. As this process continues, contrast decreases. So, both overexposure and underexposure will decrease negative contrast. Your visual quality control problem is to find the limits of useful exposure.

As in the density problem, adequate judgment of contrast is a function of experience. In gaining this experience, it's best to use a standard method of viewing the negative, varying from this standard as little as possible. A big part of this problem is the fact that all the variables of density, exposure, film, processing, etc., must be integrated when you decide upon corrective action. In effect, what you are visually examining is the density range of the negative, contrast being the difference between its maximum and minimum densities. This is virtually the only aspect of contrast you can determine by visual inspection.

Exercises (281):

1. What is the best way to check the density of negatives?

2. Give three other ways to check for density.

3. How do you check the contrast of negatives?

4. What is the only aspect of contrast you may determine by a visual inspection of the negative?

282. Give the probable cause of typical mechanical defects that degrade negative quality.

Mechanical Negative Defects. These defects are probably the ones that will cause you the most concern. They are caused by such things as improper handling of the sensitized material, equipment malfunctions, poor techniques, etc. In most cases, the blame for any of the following mechanical defects can be traced directly to the person making the photographs. This list is by no means a complete one, but it covers many of the more common errors.

a. The image appears hazy and lacking in contrast. The sun might have been shining into the lens. Light striking the lens will cause a hazy, indistinct image. Sometimes, bright light striking the lens produces large circles in which the image is partially obscured. It's also possible that your lens was dirty. Many times, dust or condensed water vapor on the lens will result in hazy pictures. Remember to clean your camera lenses frequently. The trouble could also have been overexposure, or the negative may be fogged.

b. There are fine, black, parallel lines running lengthwise on the film. This normally occurs with a film pack or rollfilm. It can be caused by the film being drawn past a sharp object before development. If you use film packs, this condition is usually caused by carelessness in withdrawing the tabs. Perhaps you jerked at the tabs rather than pulling them out slowly. On the other hand, if you are using rollfilm, this condition may be due to dirt or grit inside the camera; it may be a rough spot in the back of the camera over which the film is drawn, or it may be caused by the way the film was wound within the camera.

c. There are small, transparent, and irregularly-shaped spots. This is often caused by dust settling on the film before the exposure. It can be corrected by cleaning the camera interior and by loading the film in a clean environment.

d. There are finger marks from touching the film with your fingers. If the mark is a transparent outline of your finger, it was produced by water or grease on the fingers. If the outline is dark, the fingers were wet with developer. As we have said before, it is important to handle the film by the edges. In addition, be sure that your hands are clean and dry.

e. There are black steaks from one corner or along one side of the negative. These steaks may be caused by light that is admitted through an opening in the back of the camera. Be sure that you correctly place the film holder or film-pack adapter into the back of the camera. The camera may have a light leak caused by such things as holes in the bellows or a loose-fitting lensboard. These streaks may be caused by withdrawing the tab of the film pack incorrectly. Remember, the tab of the film pack should be pulled straight out as far as it will go. Don't press to hard on the other tabs, or an opening may be formed through which light may reach the film.

f. There are small, circular, transparent spots, or air bells. These are produced by small air bubbles on the surface of the film during development. Actually, this defect could be considered either a mechanical or a chemical defect. When the bubble breaks, the spot develops partially, resulting in a spot with less density than the surrounding area. On the other hand, if the bubble does not break, the spot is clear. The defect is mechanical if you think of one cause—lack of agitation; it's chemical if you think of the other cause—lack of development under the air bell. Other sources of air bells are improperly immersing the film in the developer, failing to keep the film in motion during development, or using water directly from the tap when the developer was prepared.

g. The negative emulsion has a wrinkled appearance (reticulation). This is produced by an abrupt or sudden swelling or contraction of the film. Sharp differences in the temperatures of successive processing solutions and/or insufficient hardening of the gelatin are the usual causes of reticulation.

h. There's a softening and peeling away of the emulsion along the edges of the film (frilling). This can be caused by warm developer, exhausted or incorrectly prepared fixer (that doesn't harden the film enough), prolonged washing, warm solutions, or handling the film too much in warm water.

i. The image shows spots of different density. This condition is caused by uneven drying. Drops of water clinging to the film cause the covered areas to dry more slowly than the rest of the film. Be sure to remove surplus water from the negative before drying.

j. There's a streak of lesser density through the center of the film. This is caused by curvature of the film, which lets the central part float clear of the developer. This is most likely if the film is not agitated properly in the developing solution.

k. There's a clear strip with a blurred edge on the negative. This is due to the bellows sagging on the camera cutting off the extreme margin of the photograph. It occurs most often with cameras having a long bellows.

l. The image is out of focus. This can mean that the distance scale is incorrect, the front lens standard is not fully extended, the lens elements aren't screwed properly in place, or the cut-film holder or film-pack adapter is not in register with the focal plane. (This may be poor technique in placing the holder or adapter in the back of the camera.)

m. Part of the subject image is cut off. Maybe the camera was moved before the exposure, the subject wasn't properly placed in the viewfinder or on the ground glass, or The viewfinder is out of adjustment or is not corrected for parallax.

n. The image is not sharp. Perhaps The subject moved. If so stationary objects in the picture are sharp, assuming that they are in focus. Lack of sharpness is confined to the parts that were in motion at the time of exposure. If the camera moved, you will see a general blurring of the image. Sometimes you will observe double lines made by the subject. Maybe the subject wasn't in focus. If other parts or objects of your negative are sharply defined while objects at other distances are not sharp, the camera was not set for the proper distance. You made an error in using the rangefinder, focusing on the ground glass, or selecting the correct distance on the distance scale.

o. There's a large, dense circle in the center of the negative. This usually results from having the shutter open and the front lens standard not extended.

p. The negative is harsh and contrasty. This comes from overdevelopment or improper lighting, resulting in strong highlights and deep shadows.

q. There is a spreading of light around the true image of a bright object on a photographic emulsion. This condition, termed "halation," is caused by light reflecting on light within the emulsion. Many film packs and sheet films have a backing that tends to prevent halation. The effect is accentuated by dirty lenses.

r. There are dense areas of varying width along the edge of the negative. This condition is produced on rollfilm when the film is not tightly wound upon loading or removal from the camera.

Exercises (282):

1. Match the negative mechanical defect in column A with the probable cause(s) listed in column B.

Column A	*Column B*
____ (1) Hazy image.	a. Insufficient agitation.
____ (2) Small areas of decreased negative density.	b. Uneven drying.
____ (3) Out-of-focus image.	c. Camera movement.
____ (4) Separation of the emulsion from the film base.	d. Shrinking of the emulsion.
____ (5) Small areas of different densities.	e. Dirty lens.
	f. Solution temperature too high.

283. State what can be done to correct discrepancies in negatives in future negative processing.

Negative Discrepancies. You should realize that there is no such thing as the perfect exposure (at least one that is good for all situations). Primarily, you must consider exposure from the standpoint of the original subject. What did you want to show in the negative and subsequent print? The answer to this question will tell you what should be shown, in the way of density, in the negative. Also, consider the factors that produced the density, such as type of film, original scene, lighting, and the processing the negative received. As one example, if the original scene were back-lighted and you exposed for a silhouette, you would have very little detail in the shadows—nor would it be desirable in this case.

Once you have noticed some defect in a negative's density, you should find the cause and try to do something about it when you make subsequent exposures. If you find consistent overexposures, there must be a cause and a curative procedure. Possibly your meter-shutter combination has cumulative errors (both in the direction of overexposure). A possible cure might be to increase the listed exposure index. Maybe you should have some maintenance done on the shutter. Regardless of the cause of overexposure or underexposure, do something about it, or your visual quality control procedures have accomplished nothing.

The major problem in manipulating contrast is that you must do it before you can see the results on the negative. Again, as in density, you may use bracketing. You can modify development to produce a series of negatives of the same subject, each one with a different contrast range. By viewing this series, you can choose the best one for printing. You can also apply the same technique to the other contrast-modifying manipulations, such as use of different films and changes in lighting. After considerable experience, you will gain the ability to make your judgments without resorting to the use of the comparison method.

Exercises (283):

1. What can you do to correct these negative characteristics during future film processing?

   a. Contrast too high.

   b. Density too low.

   c. Chemical fog.

   d. Reticulation (leathery appearance).

2-14. Altering Manual Processing

The prime objective in film processing is to produce the best possible negative. This might mean changing your processing techniques or using nonstandard solutions, but here we'll just discuss altering the processing.

284. List the processing variables that can influence the final photographic quality, and state when to change them.

Processing Variables. The three variables that we are most concerned with in manual film processing (than solution formula) are time, temperature, and agitation. Although all of these have previously been discussed in detail, let us summarize what has been stated earlier as to how these variables influence in final photographic quality. You should always remember that these variables can and should be changed whenever conditions warrant.

Exercises (284):

1. What three variables, other than processing solutions, are we most concerned with in manual film processing?

2. When should you change these variables?

285. State the effects of increasing or decreasing processing time, temperature, or agitation in producing specified characteristics.

Agitation. Agitation during film processing keeps fresh developer continuously in contact with the emulsion. If the developer by-products that diffuse out of the emulsion during development do not break up and disperse into the developer of their own accord, agitation will cause them to do so. Agitation keeps the developer solution in direct contact with the emulsion, where it can be absorbed. Also, when film is immersed into a developer solution, air has a tendency to form bubbles and adhere to the emulsion. If they're not removed by agitation, these bubbles block out the developer, resulting in areas where no density is produced. If they're just left for part of the developing time, they'll cause areas of decreased density. Developer that diffuses into the emulsion also diffuses out, carrying with it the development by-products. This same developer will reenter the emulsion, but the second time, it will be out of balance chemically, because some of its components have been used in the development process (except for the restrainer, which increases in quantity). Therefore, if the film is not agitated and the old developer is allowed to reenter the emulsion, it will retard development.

You can see that agitation is an important factor in film processing. It should also be clear that the degree of agitation greatly influences the final photographic product. That is, the more energetic the agitation, the more rapidly these three things occur, resulting in greater development action.

Developing Time. Developing times are established to produce specific photographic qualities for any one temperature and agitation combination. They are calculated to allow all the exposed silver halides to be reduced to metallic silver. Greatly extended developing time will result in large quantities of unexposed silver halides becoming metallic silver (known as chemical fog), which reduces negative contrast. In situations where a slight increase in base fog density can be tolerated, negative contrast can be increased by extending developing times. You should remember, however, that as soon as all of the silver halides in any one area of the negative are reduced to metallic silver, further development decreases contrast.

Developer Temperature. The ideal developer temperature varies with the type of film being processed. For standard emulsion, 68°F is ideal, but some black-and-white and color aerial films develop better around 80°–85° F. The influences of temperature on processing are that it expands the emulsion to allow developer penetration and it increases the activity of the developer components. (For example, hydroquinone is virtually inactive below 55°F and produces fog at temperatures 70°F.) Increasing developer temperatures lets the developer penetrate the emulsion faster, and it makes most developer components more active, resulting in higher densities and higher negative contrast. At the ideal temperature for any developer and film combination, the emulsion swells only to the point at which developer penetration is satisfactory and the activity of the developer components is repeatable.

Exercises (285):

1. How does increased developing time affect contrast and density?

2. How does decreased developing time affect contrast and density?

3. How does decreased agitation affect evenness of development and dispersion of development by-products?

286. State when photographic solutions with given characteristics should be replaced.

Solution Exhaustion. At the exact moment that a sheet of film is placed in a photographic solution, the solution begins deteriorating. All components except bromide decrease in quantity during the reduction of silver halides to metallic silver. The restrainers effect is increased by the addition of development by-products. As this condition continues, the combined effect of consuming components and increasing the restrainer slows development. Even more, a developer that has been used not replenished produces less density and contrast than a fresh developer does at the same processing time and solution temperature.

The fixing bath must stop the action of the developer and convert the undeveloped silver halides to water-soluble compounds. It stops developer action by neutralizing the alkaline solution (developer) because of the fixer's acid state. The silver halides are converted by the sodium thiosulfate, or other halide solvent, in the fixing bath. All other fixer components add nothing directly to the fixing process except to support the two chemicals responsible for these two functions.

As the fixer is used, the quantity of each component decreases. The silver halide solvent is depleted in converting the silver halides to water-soluble compounds. Transferring the developer solution to the fixing bath neutralizes the acid, increasing pH. As this happens the development action doesn't stop immediately, nor does the sodium thiosulfate completely convert the undeveloped silver halides to water-soluble compounds. Instead, it forms complex tetrathionate molecules, which are extremely difficult to get rid of during the washing step.

Exercises (286):

1. Which of these conditions indicates a need to replace the developer?
   a. A continuing decrease in contrast and density.
   b. A decrease in density with contrast unaffected.
   c. A slight discoloration of the solution.

2. Which of these conditions indicates a need to replace the fixer?
   a. The fixer clears film in less than 2 minutes.
   b. An increase in pH.
   c. The fixer feels "slick."

287. State how given solution characteristics affect negative characteristics.

Negative Quality. Naturally no conscientious photographer ever uses photographic solutions to the point of exhaustion. If there is no established procedure for solution replenishment, then the old solution is dumped and replaced with fresh solutions. At this point, let's look at some of the more common effects of exhausted solutions on negatives. When a developer is exhausted, negative contrast and density decrease and, as the preservative is depleted, the solution tends to oxidize, turn brown, and stain the emulsion. When the fixer is exhausted, the development doesn't stop immediately, so the developer remaining in the emulsion continues to produce metallic silver. This produces a stain in the areas of the negative where the continued development is greatest. In all cases, replenishment can alleviate these problems, but don't forget that while the *fixer* cannot be overreplenished, the *developer* can be. As many problems can arise from developer overreplenishment as from underreplenishment or not replenishment.

Exercises (287):

1. If a developer is overreplenished, what effect will it have on the negative?

2. What effect will overreplenishing the fixer have on the negative?

209

288. State the advantages and disadvantages replenishing by topping up.

Topping-up Method. Since developer components start to change as soon as the first film is placed in the solution, it follows that replenishment starts then and is carried on simultaneously with development. This is possible and should be done in machine processing, but it's not feasible in tray or tank development, and replenishment should be done by topping up. In this method, you keep the volume of developer constant by periodic additions of replenisher equal to the volume of developer absorbed in the processed emulsion. The main disadvantages of this method are that it allows for pronounced fluctuations in terms of density and contrast and that it doesn't compensate for the build-up in bromide. The one advantage is that it extends the useful life of developers used for manual film processing. After using a given volume of replenisher, discard the solution and repeat the procedure with fresh developer.

Exercises (288):

1. What is the main disadvantage of the topping-up method of replenishment?

2. What is an advantage of using the topping-up method of replenishment?

2-15. Examining Print Quality Visually

While it is not scientific, visual examination can greatly improve the quality of your products. Essentially, you carefully examine your product to determine whether or not it satisfies the quality requirements of the work order. Generally speaking, you should look for such things as proper density, good contrast, and various mechanical defects. With practice, you can develop the ability to recognize good and poor quality merely by looking at the product.

289. Define optimum density and state how to tell whether a print has optimum density.

Print Density. This is somewhat easier to judge than negative density. In looking for optimum print density, you look for detail in both highlight and shadow areas. Since you find the proper exposure by means of a test print, you will be able to use the test strip comparison method. The test strip includes a number of different densities, and it should be easy to choose the correct one. The major determining factor is whether you want to make an exact reproduction of the original or one with considerable alterations.

In checking print density, always make a test strip even though the negative may appear easy to print. A negative exposed under ideal conditions may be deceptive. A straight and normal print may end up with a loss of detail in both highlight and shadows. With proper analysis of the test strip, you can make corrections during printing. The test strip lets you determine a correct straight exposure, which you can selectively modify by dodging. Dodging is usually done to show detail in specific highlights or shadows, *if* they're available in the negative. If you must have shadow detail that you can't see on the negative, your visual examination of the negative will show the need for a retake before you get to the printing stage.

Estimating the exposure for a thin area of the negative is best made through experience. If you are not sure of it, try to find the right exposure by making a test of the small area. As soon as you have found an exposure that seems to be best, you will know the difference between this area and the overall exposure; thus, you know how much this area must be held back. Use the same technique to determine of how much added exposure (burning-in) you need on the heavily exposed highlights (dark areas) of the negative. By analyzing the negative and applying the appropriate corrective measures during printing, you should produce the best possible result. Just because negative density is not perfect is no reason for reshooting. Through quality control, you can make a negative of imperfect density yield an acceptable print.

Exercises (289):

1. What is meant by optimum print density?

2. What areas of the print are you concerned with in evaluating for optimum density?

3. When you must have detail in the shadows and you cannot see details in the negative, what will you have to do before the printing stage?

290. Define optimum contrast and state what factors determine whether a print contains optimum contrast.

Print Contrast. The contrast of a print is largely based on the negative's density range and the printing paper's contrast. Remember, however, two negatives of different subjects could have the same printing contrast but have different density ranges. Since the negative's contrast is fixed before you print, any contrast corrections at this point are made by changing the paper. The ideal is to have a normal negative that can be printed on normal-contrast paper. But what is normal? As in our previous situations, the comparison method of determining the best contrast of paper is again advisable. The negative may have normal contrast, and maybe it should be printed on normal contrast paper. You must judge this, but your judgement will be improved if you make one print on each of several contrasts of paper and then pick the best print. The print made on normal contrast paper may look good by itself, but by comparing it with others, you may get an even better print. Make the best print you can on each of the paper contrasts, view the prints under normal lighting conditions, and then make your final choice. If the prints are wet, blot them to eliminate the high gloss, and don't compare a dry print with a wet print. Try to standardize the viewing conditions as much as possible, consistent with normal laboratory procedures.

Exercises (290):

1. On what two things is print contrast quality based?

2. What is optimum contrast?

291. Categorize defects that degrade print quality as mechanical or chemical defects, and indicate the cause of each.

Mechanical and Chemical Print Defects. These defects often result from essentially the same reasons as negative defects. The following causes of defects in prints can help you recognize and remedy lack of print quality.

a. If the print is too dark, it may be caused by overexposure, overdevelopment, developer too warm, negative too weak or thin, or using the wrong contrast.

b. Grayish-whites over the entire print are usually caused by chemical or light fog, insufficient potassium bromide in the developer, too long a development time, outdated paper.

c. A grayish-mottled or granulated appearance of the edges or entire print is usually caused by underexposure and forced development. This effect may also be caused by using outdated paper. Moisture within the paper or exposure to chemical fumes such as ammonia can also produce this effect.

d. d. If the print is too light and lacks detail, the problem may be caused by underexposure, underdevelopment, or cold developer.

e. Brown or red stains are usually caused by exhausted or oxidized developer or by fixing baths low on acid, or improper agitation in the fixer.

f. A purple discoloration (hypo-developing stain) of the print is caused by lack of agitation in the acid stop bath.

g. Greenish or brownish tones (sometimes mottled) are caused by exhausted, badly discolored, or cold developer. These tones can also be caused by an excess of potassium bromide, and they are sometimes caused by overexposure and underdevelopment.

h. Round white spots on the prints are caused by air bells on the surface of the paper. To avoid air bells, develop your prints face up, immediately brushing off any air bells that form on the surface. Be sure to use enough developer to cover the prints completely.

i. Round or irregular dark spots on the prints are caused by air bells that form when several prints are allowed to stick together in the fixing bath.

j. Yellowish-white stains all over the print are the result of underexposing and forced development. They may be caused by not agitating the prints during the first few seconds after immersion in the fixing bath. They may be the result of weak developer, insufficient fixing and washing, iron in the wash water (which may come from rusty pipes), sea water, or dirty drier belts contaminated with fixing solutions.

k. White deposits over the entire surface of a print are caused by milky hypo baths and incorrectly mixed or impure chemicals.

l. *Freaking* is an unpredictable phenomenon that crops up in many forms. Freaking marks sometimes look like fingerprints or greasy streaks. At other times, the print may look as though an area of the paper has no emulsion. In general, freaking is the result of an exhausted or overdiluted developer. It is accentuated by uneven immersion in the developer and also by high humidity. The remedy for freaks is to discard the developer and mix a fresh solution. When conditions are extremely unfavorable, you may have to use a more concentrated solution and increase slightly the amount of sodium carbonate in the formula. In some cases, freaks can be prevented by immersing the print in water for a few seconds after exposure and before development. (1) One package of paper may freak in a certain developer, while another package of the same paper will not. This is not proof that the paper is defective, but it simply shows that the two packages have been stored under different conditions at some time. (2) Both packages of paper, however, will give good results with correct development. The temperature of the developer is important. A solution that is too cold is more likely to produce failures than one at normal temperature.

m. Excessive curl of unprocessed paper is usually caused by storing paper near heat. Curl in processed paper is caused by rapid drying in excessive heat or low relative humidity.

n. Paper shrinkage or stretching often happens during processing. To avoid shrinkage, keep processing solutions at the proper right temperature and avoid high drying temperature. To prevent stretching, don't pull the material while it's wet.

o. Fingerprints on prints are caused the same ways they are on film. They can be dark (developer on the hands) or white (fixer or normal body oils on the hands).

p. Printing paper is also subject to abrasions or scuff marks, which show up as black or gray marks or lines. These marks are best avoided by careful handling of the paper.

Exercises (291):

1. Categorize each print defect as chemical, or mechanical and give it's probable cause.

   a. Dark fingerprints.

b. White fingerprints.

c. A print of a black-and-white line drawing that is gray where it should be white.

d. Purple stains.

2-16. Additive and Subtractive Color Processes

The various screen processes developed in earlier days all followed the *additive color process*. All color processes in use today start with this additive color process. Here we use the primary colors of blue, green, and red.

292. State the results of given color combinations.

Additive Primary Colors. When equal parts of blue, green, and red light are projected from separate projectors and partially superimposed on a white screen, you see white in the area of overlap of all three colors. The area of overlap between the blue and green light produces *cyan* (blue green), the area of overlap of the red and blue light produces *magenta*, and the overlap of the red and green light produces *yellow*. You can get almost any color match you want by varying the amount of one of the two colors that produce that color. For example, if you have equal proportions of red and green, the result is yellow; by increasing the amount of red, the result is orange. Since matching a wide range of colors with red, green, and blue light involves adding of the colored light, the primary colors are often identified further as the additive primaries.

Exercises (292):

1. What color is the light produced when these color combinations are superimposed on a projection screen?

   a. Red and blue.

   b. Green and blue.

   c. Red and green.

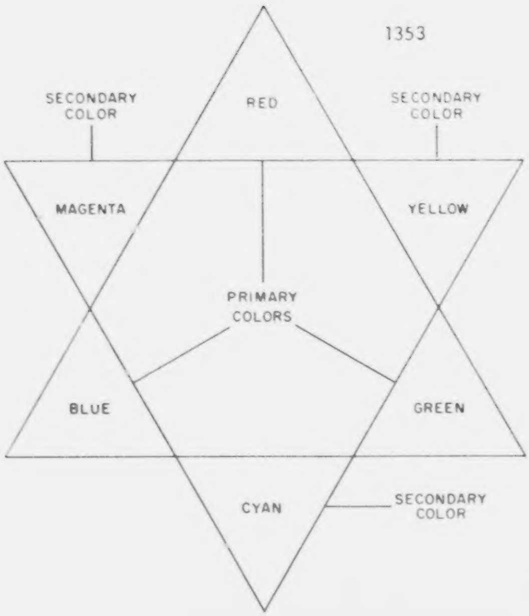


Figure 2—19. Color star.

293. Use illustrations of additive filters to identify the color of light that will be transmitted by a filter or produced if two or more filters are projected on the same screen.

Additive Principles. In color photography, the three colors produced by mixtures of the additive primaries in pairs are of particular importance. These colors-cyan, magenta, and yellow-are known as the subtractive primaries. Since each represents white light minus one of the additive primaries, the subtractive primaries are the complements of the additive primaries. For example, cyan and red light blend together to give white light. Similarly, magenta is complementary to green, and yellow is complementary to blue.

At this point, refer to figure 2-19 and study the illustration of the color star. Remember which colors are the additive primaries (blue, green, and red) and notice that the subtractive primary colors between any two of the additive primaries are mixtures of these two primary colors. Also, notice the colors that are directly opposite to each other in this star; these colors are complementary to each other.

Although the original photographic record on color material uses the additive primary colors, these are not suitable for the final color product in general use. You need three filtered light sources, such as those produced by three projectors, for additive color mixtures; but for practical purposes, most color transparencies or prints must be viewable with only one white light source (made possible by the use of the subtractive color process).

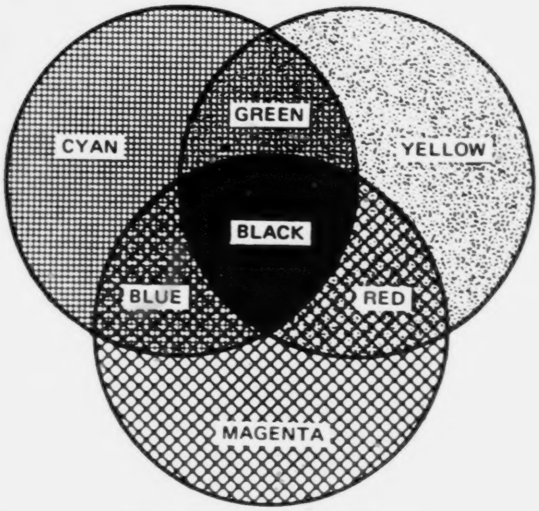


Figure 2-20. Subtractive color process.

Exercises (293):

1. What color light is transmitted by these filters?
   a. Red.

   b. Blue.

   c. Green.

   d. Blue and green.

2. What color will be produced when light through each of these filters falls on a screen?
   a. Red and blue.

   b. Blue and green.

   c. Green and red.

   d. Green, red, and blue.

294. Use illustrations of subtractive primary filters to identify the color of light that will be transmitted by the filters or produced if two or more filters are projected on the same screen.

In the additive color process where three projectors were used (one lens was covered with a red filter, one with a green filter, and one with a blue filter), we were able to produce any desired color. Theoretically, any filter transmits light of its own color and absorbs all other colors. The amount of absorption depends on the density of the filter. Therefore, we could not place all three filters over a single light source. To a certain extent, the filters are mutually exclusive; that is, none of them transmits light passed by either one of the other two. Consequently, any two of the filters used in combination in front of a single light source absorb all of the light.

Since a filter of any of the additive primary colors transmits only that one primary color, the subtractive primary colors are used as filters in the structure of color materials. This makes it possible to transmit any two of the additive primary colors and subtract the third.

Subtractive Principles. A cyan filter transmits blue and green light but absorbs red light; hence, it subtracts red from white light. Similarly, a magenta filter (which transmits red and blue) does nothing more than subtract green from white light. Finally, a yellow filter (which transmits red and green) functions by subtracting blue from white light.

Since each of the subtractive primary filters transmits approximately two-thirds of the spectrum, we can superimpose any two of them over a single light source to produce other colors. Figure 2-20 illustrates the *subtractive color process*. Notice that combining of any pair of the subtractive primary colors in equal densities produces one of the additive primary colors. For example, a yellow filter transmits red and green and absorbs blue, and a magenta filter transmits red and blue and subtracts green from the light source. When these two filters are used over a single light source, the one color that is transmitted by both magenta and yellow is red. Therefore, yellow plus magenta produces red.

When yellow and cyan are used in combination, the one color that is transmitted by both filters is green, since yellow transmits red and green, and cyan transmits blue and green. Cyan plus magenta produces blue, because blue is transmitted by both filters. Where all three filters overlap, all of the light is subtracted, and the result is black. By varying the density of one of the filters, you can make color change you want. For example, to change red to an orange red, increase the amount of yellow; in other words, decrease the amount of magenta.

As we said earlier, color photography first applies the additive process to all color materials; then during the final stages, the subtractive process is used to reproduce the original color of the subject. Sound understanding of how these two processes apply to color photography is fundamental to learning about color image formation.

Exercises (294):

State which primary colors are transmitted by the filters in items 1–3, below and those in terms 4–7 on figure 2-21.

1. Cyan.

2. Magenta.

3. Yellow.

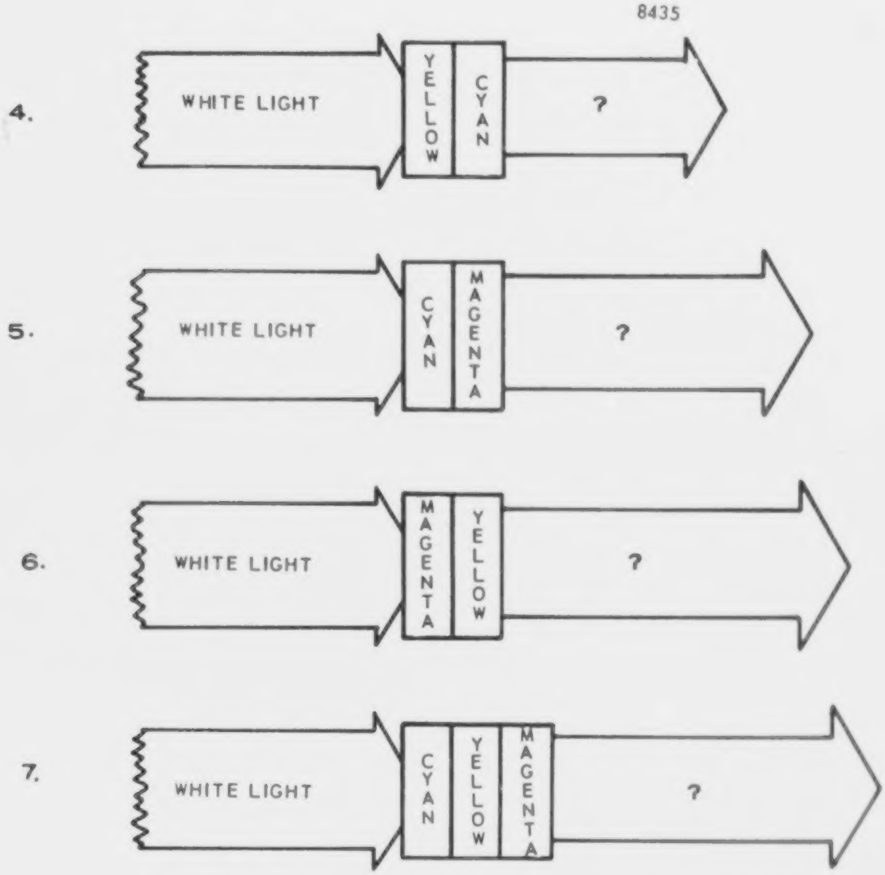


Figure 2–21. Subjective primary filter transmission (objective 294, exercises 4–7).

2-17. Color Printing Requirements

The production of a fine color print has been called the ultimate in photography, and for years it was also the most difficult to achieve. However, with the introduction of good color-negative films and paper, color printing is as flexible and practical as black-and-white printing. Of primary interest to the lab technician is the negative-positive method for production prints of high color fidelity with a full range of tones. Also of special interest is the latitude of lab control over the finished product—control that lets you compensate for slight overexposure or underexposure, dodge, or burn in. Specifically, areas can be darkened or lightened, and colors and tonal ranges can be controlled. Also corrections and changes can be made by handwork on the negative or print.

295. List the factors to consider in selecting color printing equipment, and tell how these factors will affect the product.

Printing Equipment Requirements. In considering the requirements for color printing equipment, you run into two of the same factors that can create problems in exposing color film in the camera: intensity and time. In the printing equipment, however, there are other interrelated considerations. For example, you consider the color temperature of the light source, the potential for using corrective filters, the quality of the lens, the accuracy of the timing device, light leakage from the printing equipment, and the ease of operation in total operation.

Color Temperature. Throughout your training in color photography, you have constantly been reminded of the fact that the color temperature of the light used to expose the color material must match the color material spectral sensitivity. This is true for the original exposure, and it is no less true for the printing stage. In printing equipment, color temperature is usually regulated by the choice of the lamp, by the regulation of the voltage applied to the lamp, and by the addition of light-balancing filters to the light source. If the light source in the printer is to be ideal for color printing, you must be able to change its color temperature and to sustain the value once it is established.

Corrective filters. In color printing, the three emulsion layers in the printing material must be correctly exposed from the three color records in the negative. The exposure of these three layers is manipulated both by the exposure time and the color of the light reaching the paper. You control the color of the light by placing color filters in the light beam of the enlarger. Use either color-printing (CP) or color-compensating (CC) filters. In addition to a set of corrective filters to absorb ultraviolet radiation emitted by the light source, you need a Wratten 2B or CP2B filter.

Certain printers are designed to hold the correction filters in the printer head (between the light source and the material that is to be printed). This placement is preferable to having the filters between the material being printed and the sensitized material that is to record the image, because it minimizes such effects as dust and scratches in the filters. Some printers have sets of correction filters built into the printer head, so that you can select the filters by rotating control knobs on the exterior of the printer.

Lens quality. Correction for chromatic aberration discussed earlier in this volume is the same (and just as critical) as it is in the camera.

Accuracy of timing. Just as the exposure latitude of the film you use for taking the color photograph is narrower than that for making black-and-white negatives, so also is the exposure latitude of color-printing material. For this reason, accuracy of exposure timing is essential to the production of good color prints. Your printing equipment must be capable of producing consistent, accurately timed exposures.

Light leakage. Printing equipment for making color prints must be so designed that the light escapes only through the lens opening. Because of the high sensitivity of the color-printing materials, extraneous light fogs the materials and degrades the product. Before you start any color printing with existing equipment, you may have to block off minor light leaks, even though they produce no significant problems when you work with black-and-white materials.

Ease of operation. Color-printing materials are sensitive to all colors of light. Because of this, you must be able to work rapidly, effectively, and precisely with your printing equipment in total darkness. This is not an easy task; it takes complete familiarity with the equipment and a good sense of touch. If you can't master your equipment under total darkness, you can't expect to produce consistently good color prints without wasting materials.

Exercises (295):

1. What factors should you consider in selecting color-printing equipment?

2. What will happen if you use a 3800 K exposing lamp to expose material balanced for 4200 K?

3. A projection printer doesn't provide for using corrective filters, so you attach a filter holder to the bottom of the projection lens. If the printing room is not completely void of dust, dirt, and other foreign matter during printing, what can you expect on the prints?

296. List the purpose and types of filters used during exposure of color film.

Exposing Color Film. The modern color emulsion is relatively simple to use. In contrast with the problems inherent in earlier color processes, the present-day emulsion is highly standardized and effective. Even so, you must control your product. It may be true that exposing a color transparency is no more difficult than exposing a conventional black-and-white negative, but if you want consistently good results under varying conditions, you need the knowledge that lets you realize the full potential of the film you are using.

Why must you use filters to modify the light when you are using color film, yet not need them over your eyes for normal color perception? The color receptors of the human eye compensate for minor variations in the primary colors. For example, if an automobile looks red to you in sunlight, it also looks red to you when you view it under any other lights that are reasonably close to being white.

Although the difference in the quality of the illumination actually affects the quality of the light reaching the retina, an automatic compensation takes place in your brain. Color films have no such automatic compensation device. They reproduce colors approximately as the human eye sees them only when the films are exposed with the same light quality for which they have been balanced.

Since color films can't compensate for the fluctuation in color quality of light, you must use filters to modify the light any time it is not absolutely correct. If the light is properly filtered before it strikes the emulsion, the resulting exposure appears much the same as did when the scene was viewed. The filters used with color films may be generally classed as conversion, light-balancing, color-compensating (CC), or special-purpose filters.

TABLE 2-2

LIGHT BALANCING FILTERS

COLOR	"WRATTEN" NUMBER	EXPOSURE INCREASE IN STOPS*	COLOR TEMPERATURE SOURCE	
			CONVERTED to 3200K	CONVERTED to 3400K
Bluish	82C + 82C	1⅓	2490K	2610K
	82C + 82B	1⅓	2570K	2700K
	82C + 82A	1	2650K	2780K
	82C + 82	1	2720K	2870K
	82C	⅔	2800K	2950K
	82B	⅔	2900K	3060K
	82A	⅓	3000K	3180K
	82	⅓	3100K	3290K
No Filter Necessary			3200K	3400K
Yellowish	81	⅓	3300K	3510K
	81A	⅓	3400K	3630K
	81B	⅓	3500K	3740K
	81C	⅓	3600K	3850K
	81D	⅔	3700K	3970K
	81EF	⅔	3850K	4140K

* These values are approximate. For critical work, they should be checked by practical test, especially if more than one filter is used.

Exercises (296):

1. List the filters to use during exposure of color material.

2. Why must you use filters?

297. State what filter type is most appropriate for typical work situations.

Conversion Filters. Use conversion filters to expose tungsten-type color films under daylight illumination conditions or to expose daylight-type color films under tungsten illumination conditions. Conversion filters are probably the most common of all the filters used in color work.

Type A color films are balanced to produce an exposure with photographic floodlamps producing 3400 K illumination. When a Wratten 85 filter is used with type A film, daylight illumination converts to the right color temperature for color balance. Type B color films are balanced for studio lamps burning at 3200 K. This film can be exposed under daylight illumination with a Wratten 85B conversion filter.

Because of the great loss in film speed, daylight color film is not normally recommended for use with tungsten illumination, but there are filters available for this purpose if the need arises. Use the Wratten 80A filter when you expose daylight film with photographic floods or studio lamps operating at 3200 K.

Light-Balancing Filters. The Kodak Wratten 80 and 82 series filters are useful for changing the color quality of certain tungsten light sources to balance the light for the tungsten-type color films. Using Wratten 82 (bluish) filters is equivalent to raising the color temperature of the tungsten source, and using Wratten 81 filters (yellowish) is equivalent to lowering the color temperature.

Observe table 2-2. The last two columns (with the exception of the Wratten 81EF filter) show how the filters are graduated in steps of approximately 100 K. Remember that these increments approximate 100 K only when the filters are used for balancing tungsten illumination. These filters would have different corrective effects if they were used on other illumination. Within the 81- and 82-filter series, use the odd-numbered filters to lower the color temperature. They filter out the blue, and they usually appear yellowish or reddish orange—the color is often referred to as *salmon*. Use the even-numbered filters to raise the color temperature. They filter out the red, and they usually appear bluish.

Color-Compensating (CC) Filters. Use color-compensating filters to make minor color changes in the color balance you get in exposing color films or color print materials. They compensate for deficiencies in the quality of the printer light sources or transparencies. You can introduce almost any correction you want by using the filters singly or in a variety of combinations.

Eastman Kodak supplies color-compensating filters in six colors: the three additive primaries and the three subtractive primaries. These compensating filters come in six different densities for each of the six colors. The densities start with 0.05 and then progress to 0.10, 0.20, 0.30, 0.40, and end with 0.50. Density is measured in terms of the wavelength of maximum absorption. For example, the density of a yellow filter is in terms of the amount of blue light it absorbs. The density value of the compensating filters does not include the neutral density of the base material—density of the gelatin plus the glass (if mounted in glass).

The most common color-compensating filters are made in the form of sheet gelatin and may be used in the path of image-forming light. If you use several filters together, definition and contrast are adversely affected by light scattering, so you should always use the minimum number of filters that will produce the desired correction.

Special-Purpose Filters. Special-purpose filters are designed to improve your color photographs, but they don't alter the overall color balance of the light. Use skylight filters, which absorb ultraviolet energy and a small part of the blue and green light, when you are making photographs in open shade under a clear blue sky. Under these conditions, if you make pictures without a filter, the results often appear too bluish. Ultraviolet (UV) filters are those whose absorption is limited mainly to the ultraviolet radiant energy. They have little effect on the visible portions of the electromagnetic spectrum and, thus, have little visible effect (with the exception of eliminating the exposure caused by ultraviolet radiant energy). Do not use skylight filters or ultraviolet filters when tungsten films are exposed under bluish daylight conditions, because the conversion filter adequately absorbs the excess radiation in this portion of the spectrum.

With the color films, the effects of light-blue haze can be minimized if you use a Pola-Screen over the lens. (Saturated color filters cannot be use for this purpose as they are when you are using black-and-white materials, because the overall film-light color balance will be altered.) A Pola-Screen is approximately neutral in color through the entire visible spectrum. Thus, it produces no pronounced cast of color in the photographic results.

The effect of the Pola-Screen can be observed by viewing the scene through the filter and observing the effects or by placing the filter over the lens of the camera and observing the effects on the ground-glass image. Slowly rotate the filter until you get the effect, you want and then use the filter in this exact position. Maximum darkening of the sky or maximum haze penetration takes place under conditions of top lighting or side lighting and in the area that is approximately at right angles to the direct rays of the sun. The filter factor of the Pola-Screen is about 1½ stops for maximum filtering, but for very critical work, you should test the filter factor.

Exercises (297):

1. What type of filter should you use in each of these work situations?

   (1) You are photographing a high mountain pass.
   (2) You are exposing daylight film to a tungsten light source.
   (3) You want to decrease the effects of atmospheric haze in color aerial photographs.
   (4) During color printing, you need to make a print appear slightly warmer in tones.

298. Give the lighting requirements for typical work situations, and state how these requirements are satisfied.

Lighting. For good color reproduction, you should usually keep the lighting ratios low, and you should keep the light distribution over the entire subject area fairly even. The tonal contrast of a color transparency or a color print depends more upon subject colors and color distribution that it does upon shadow and highlight differences. In color work, the shadows reproduce much darker than they appear to your eye, so shadow detail tends to be lost unless you keep lighting ratios very low.

Lighting ratio. The term "lighting ratio" commonly refers to the ratio of the intensity of the key light (or modeling light) to the intensity of the fill-in light. In terms of the results produced with color film, it is the ratio of the *key light plus the fill-in light* to the fill-in light alone. If a color transparency is to be printed, use the lighting ratio that does not exceed 3 to 1 for average subjects. For subjects that don't have a wide range of reflectances, use a 4- to 1-ratio. If transparencies are intended only for viewing, use lighting contrasts up to about 10 to 1 *for special effects*. (The reason such a ratio is permitted is that transparencies can produce a much greater range of tone values by transmitted light than can color prints by reflected light.)

You can use light meters to determine lighting ratios by reading either the incident light or the reflected light. Incident-light meters are designed to read the different light intensities directly. When you use a reflected-light meter, a neutral test card becomes very helpful.

To read the key light plus the fill-in light, hold the incident-light meter or the test card close to and in front of the subject, and turn the meter or test card to the position that gives the maximum reading. When you use an incident-light meter, all lights may be on. When you use the test card and the reflected-light meter, turn off any back lights or side lights that may influence the meter reading.

When you read the fill-in illumination (any frontal illumination used primarily to light the shadow side of the subject), be sure you turn off the key light. Turn the incident-light meter or the test card toward the camera lens. When you read the test card, hold the meter about 6 inches away from it and make sure that no shadows from the meter or from any part of your body affect the meter reading.

The lighting ratio is between the key light plus fill-in light reading and your fill-in light reading. For example, if the key light plus the fill-in light is 18 and the fill-in light by itself is 6, the ratio is 18 to 6 or 3 to 1.

For an example of this method of determining lighting ratios, we use lights of equal intensity in the lighting of a portrait. Place a fill-in light close to the camera; then place the key light out and away from the camera and above the camera level, but at the *same distance* from the subject as the fill-in light. The area of the subject illuminated by the key light plus the fill-in receives two units of illumination: one unit from the key light and one unit from the fill-in light. The shadow area illuminated only by the fill-in light gets only one unit of illumination.

Outdoor lighting. In shooting color film outdoors, you can control ratios much the same as you can indoors; i.e., by using reflectors or flash for fill-in lighting. Dividing the f/stop number into the guide number (for the shutter speed being used) gives the flash-to-subject distance in feet for an approximate 4- to 1-ratio. Experience teaches you how much to deviate from this basic calculation to get the ratio that yields the best results.

Light distribution. You must provide adequate illumination over an entire scene to maintain detail and normal color in all areas. To check the evenness of illumination, you can use an incident-light meter pointed toward the camera or a reflected-light meter, reading a test card held so that it faces the camera. Turn out side or back lights that might affect reflected-light meter readings.

Make the meter readings over the entire scene if you want normal color. You may need supplementary lighting for areas of exceptionally low illumination. Some backgrounds, such as dark drapery materials, may require more light than that used to illuminate the subject.

Exercises (298):

1. What are the two main lighting requirements for exposing color materials?

2. What lighting ratio should you use for color portraits?

3. How can you assure adequate lighting throughout an entire scene?

299. Identify flaws in processed color materials with their probable causes or results.

Exposing Reversal Color Film. Any reversal process, whether it is black-and-white or color, is very critical with respect to exposure. Remembering some your experiences, can you recall times when you made an error in computing an exposure? You may have overexposed or underexposed by one or even two stops. The negative looked dark or light, but the error was rectified in printing. Don't make this mistake with color. Any deviation from a correct exposure is an error that increases, because this is a reversal emulsion.

For any reversal process, there is only one truly correct exposure; one that will give the best reproduction of the subject. This correct exposure will use up about 50 percent of the film's ability to form a silver image. The rest of the total ability is then available ~~to~~ produce the positive and the color image. You can deviate from the correct exposure for special effects, but it will be to your advantage to use the correct exposure in most cases.

Underexposure of a subject uses less than half of the film capability. When the positive image is formed by reversal, all of the remaining silver halides are exposed and most of them are developed. This second development will therefore produce positive silver and dye images proportionately greater than the negative image. This is why an original underexposure produces a heavy, color-saturated positive. The opposite, of course, is true for an overexposure, where the result is a thin, washed out, weakly colored transparency. Usually color films have a latitude no more than half an f/stop.

Exposing Negative Color Film. The printing advantages of using color negative film rather than color positive film far outweigh the one significant disadvantage. Negative color film's latitude approaches that of black-and-white film (except for color contrast limitations). It can be processed in about half the time it takes to process reversal films. Color prints can be made directly from the color negatives—using Kodak Ektacolor paper, and positive transparencies can be printed from the negatives on vericolor print film. Black-and-white prints can be made on panalure paper.

The main disadvantage of the negative color film is that it's hard to predict visually the quality of the positive color that will be produced from the negative. However, this is not a serious problem, since there are methods for determining quickly and economically the exposure conditions for printing color negatives.

Kodak professional negative color sheet or rollfilm comes in two forms: Vericolor II Professional S and Vericolor II Professional L. It is important that you understand the difference between them. *Type S film* is designed for short exposures. It is specifically for making color negatives at exposure times of 1/10 of a second or shorter. It is balanced for use with electronic flash, blue flash, or daylight without a filter. With the appropriate filter, the film can be exposed with clear flashlamps.

Type L film is designed for long exposures. With it, you can make color negatives at exposure time ranging from 1/10 of a second to 60 seconds. It is balanced for use with 3200 K lamps *without* filters and can be exposed under photographic flood or daylight illumination by using the appropriate filters. Its exposure index varies with the exposure time you use. For example, the film has an effective speed of 100 with a 1/10-second exposure and 3200 K illumination. The speed is only 32 with that light and 60 seconds' exposure. This change of exposure index helps counteract color shifts from reciprocity failure.

Rollfilm. Negative color rollfilm, known as Kodacolor II film, is a dual-purpose negative color film supplied in standard rollfilm sizes. It is designed for exposure using daylight illumination and for exposure using blue flashlamp illumination with the use of filters. Using photographic floods and 3200 K lamps is not recommended, but satisfactory results have been produced using these sources and the proper correction filter.

Long rolls of various widths of Kodak Vericolor film without a type designation are for use in identification portraiture. Negatives made on this type of material are essentially the same as those produced on type S Vericolor and may be printed the same way.

Negative quality. The most important single characteristic of a color negative for color printing is that it have adequate shadow detail. The exposure latitude of the film depends on subject color, subject contrast, and the lighting ratios you use. Exposure latitude ranges from about one-half stop under to two stops over. If there is any doubt about the right exposure, *overexpose* rather than *underexpose*. An overexposure negative tends to print warm or yellowish, but the results are not too objectionable. If the color negative is underexposed, the color balance will be off. If you try to correct for the shadow areas as you print, the highlights tend to go too warm or too reddish; if you try to correct for the highlights, the shadows tend to go too cool or bluish.

You can't tell the color balance of the color negative visually, but you can evaluate the adequacy of exposure. If there is no visible shadow detail and the shadow areas are clear orange, the negative is underexposed. When the highlights are blocked up, the negative has been overexposed. Evaluation of color negatives may seem very difficult when you first work with them because of the orange masking. You can overcome this by viewing the negative through a Wratten 61 green filter. This filter neutralizes the orange masking and lets you read the shadow and highlight areas for detail.

To help determine the color balance of Vericolor negatives, photograph a neutral gray card with the subject. Place the card along the edge of the scene where it doesn't interfere with the subject, but does get the same lighting. If you can't do it this way, photograph the card with the full subject lighting, using a separate sheet of film. Process this test film with the same batch of negatives as the subject that it represents.

In exposing negative color film, you should keep the lighting ratio low, preferably 4 to 1 or less. Also, you should follow the manufacturer's recommendations for filtering, especially when critical color balance is necessary. For example, a Wratten 80C filter is recommended for exposing type S Vericolor film with clear flashlamps. This balances the exposure, giving balanced dye filters in each of the negative layers. If you don't use the filter, the excess of red in the light affects the film so that the dyes are unbalanced. Although you can make some corrections during printing, it's hard to get equal balance.

Reciprocity Law Failure. Reciprocity failure is a serious problem in color photography because of the multilayer makeup of color films. Extremely long (e.g., 5 seconds) or short (e.g., 1/2000 second) exposures are likely to cause color shifts with color negative films, so it's important to read the manufacturer's exposure recommendations for the film you are using.

Suppose you're using a film that has an exposure index of 32 for a 1/2-second exposure and an exposure index of 25 for a 1/50-second exposure. This means that at the 1/2-second exposure level, the sensitivity of the film is maximum. A lower illumination level has less effect, even though it is compensated for by a proportional amount of adjustment on either the shutter or diaphragm. This same effect is also apparent at higher illumination levels. Not only is this effect of reciprocity failure noticed in latitude, but is also plays a large part in changing the color balance of the film, since each layer of the tripack is affected to a different degree. So you see, not only must you compensate for a change in film speed at other-than-recommended exposures, you may also have to use a filter to correct the color balance of the emulsion at the new exposure level.

Exercises (299):

1. How will an overexposed color slide appear?

2. When you are exposing color negative material and you are not quite sure, of the exposure, should you lean toward underexposure or overexposure? Why?

3. How can you tell visually whether a color negative is properly exposed?

4. What effect does the reciprocity failure have on color emulsions?

5. What's the probable cause for dark, saturated colors in a transparency?

6. What's the probable cause for excessive blue in the shadow areas on a print made from Kodacolor II?

2-18. Mixing Color Solutions and Processing Materials

Pioneers in black-and-white photography spent considerable effort to eliminate the stains on the films caused during processing. Many developing agents were tried, including chemicals that weren't needed to develop the film. They often got different colored stains that way, but except in specialized cases, stain was undesirable. Finally they found a chemical (sodium sulfite) that prevented the formation of the organic dye that caused the stains. Thus they got a good, clear, black-and-white image. Little did these early experimenters realize that they were very close to the principle of color development. The chemical reactions that caused the stains were the basis of the newly discovered dye industry. At the time, it just wasn't realized that those principles could be applied to color photography.

300. State what happens during the second development in the coupler developer process.

Coupler Development. In the dye coupling method, a chemical dye coupler is added to the emulsion. When this coupler contacts other dye in the color developer, a colored

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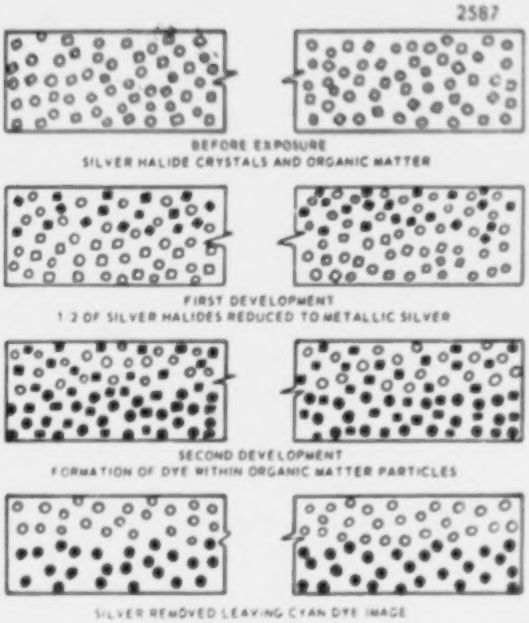
2587
BEFORE EXPOSURE
SILVER HALIDE CRYSTALS AND ORGANIC MATTER
FIRST DEVELOPMENT
1/2 OF SILVER HALIDES REDUCED TO METALLIC SILVER
SECOND DEVELOPMENT
FORMATION OF DYE WITHIN ORGANIC MATTER PARTICLES
SILVER REMOVED LEAVING CYAN DYE IMAGE

Figure 2-22. How cyan dye is formed in the reversed image of the red-sensitive layer.

dye forms. Thus, the original exposure controls the production of just enough dye to give the right amount of color. The dyes are formed simultaneously with the reduction of silver halides and are present in proportion to the amount of black metallic silver produced.

As we've seen, exposure of color film is critical, not only from the standpoint of correct color reproduction but also because of the nature of reversal type emulsions. For the same reasons, processing is just as critical. Minor errors in temperature control, film agitation, and processing time can be overcome in black-and-white work. If you make the same mistakes in processing color, you have something left called experience, but that is all.

Most of the varieties of color film currently on the market are similar in construction and processing, but the chemicals used for processing are not interchangeable. Use only the chemical kits supplied by the manufacturer whose film you are using, and stick very closely to the instructions in the kit.

Reversal color film must be developed twice. The first development is essentially the same as any black-and-white process. The second development takes a color developer, in which the colored dyes are formed. As the color developer reduces the silver halides in the emulsion, the action also oxidizes the developer itself. The oxidized developer then combines with the emulsion's *coupler* to produce the colored dye. Formation of this dye is proportional to the amount of silver that is reduced—the greater the reduction of silver, the greater the production of dye. You can see this in processed unexposed color film, which comes out completely black because the maximum amount of all the dyes was produced.

The process of dye formation is illustrated in figure 2-22, which shows only the red-sensitive layer, but the same composition exists in each of the three layers. After you immerse the film in the color developer, the developing agent penetrates the particles of organic matter and reacts with the coupler. The color of dye formed depends on the type of coupler you use in each layer.

Exercises (300):

1. What takes place during the second development in color film processing?

2. How would a color transparency appear if it had been processed but not exposed in the camera? Why?

301. State why you should follow the manufacturer's instructions for mixing color chemicals, and state what two factors have the greatest effect on color processing.

Preparation of Solutions and Equipment Requirements. Manufacturers of color film, as we've said before, prepare processing kits that have all the chemicals necessary to develop their product. These kits all come in many sizes, and the size you should choose depends on the amount of film to be developed. The manufacturer recommends the maximum amount of film to be processed in any one kit. As with other processing solutions, these kits deteriorate in time. Certainly it is poor economy to use a 3½-gallon kit to develop only 6 sheets of film that could be processed with only a pint of solution.

When you are processing color materials, it is absolutely essential that you faithfully follow the manufacturer's instructions for mixing the solutions and for carrying out the processing steps. These instructions are not difficult, but they are exacting and they are subject to change. Always read the literature packaged with the materials. All steps must conform to the current instructions supplied with the material and must be standardized so that they are *repeatable* from one time to the next. Then, you can get correct, *repeatable* results. Don't introduce personal variations that may be due to your past experiences with *other* color materials or *other* color processes.

How can you achieve repeatable results? At this point in your training, you can understand the reasons behind strict adherence to manufacturer's instructions, since you know that color materials and processes change as improvements are developed. Your main task is to select intelligently each piece of equipment used in processing color materials. In making this selection, you must carefully weigh the performance capabilities of the processing equipment in producing top-quality, repeatable results. You must consider any factor that affects the finished product. Two of the factors that have the greatest effect on the color processing are temperature control and agitation control.

Exercises (301):

1. What are the two main considerations for color processing equipment?

2. Why must all mixing steps conform to the instructions supplied with the material?

302. Identify proper methods of temperature and agitation control and state how improper temperature control affects the characteristics of processed materials.

Temperature Control. When you are processing color materials, temperature tolerances are very limited; and even minor deviation from the established standards may result in emulsion speed changes and color balance shifts. Physical damage, such as reticulation or frilling, is likely to occur if the temperature of solutions goes out of control or if there is a major difference in the temperature of the various solutions.

If you are processing only a small quantity of color materials, you can get along with a simple water-bath adjustment of temperature. One way to establish water-bath temperature control is to fit a standpipe into the sink drain with the standpipe's height slightly less than the level of the solutions in the processing tanks. You can then fill the sink to the top of the standpipe with tempered water that you adjust to the specified solution temperature. The tempered water overflowing from the wash tank will keep the water bath at the right temperature *if* you carefully regulate the input of wash water. If you use an ordinary, nonregulated hot and cold fixing valve for this type of temperature control, you must monitor closely the temperature of the incoming water and the temperature of the water bath, since varying loads on the water supply lines may change the temperature of the mixed water.

When you process color materials on a mass production basis, you must use a more accurate and dependable temperature-control system. One such system has, at its heart, a thermostatically controlled water-mixing valve hat keeps its water output at a constant temperature. To maintain the temperature of a 3½-gallon color processing setup, such a valve must have a flow capability of at least 3 gallons per minute. There are several different types and models of color-processing sinks that assure accurate solution temperature by feeding the water-bath system from a thermostatically controlled mixed valve. For quantity color production, these sinks help make consistent high-quality work possible.

Agitation Control. Proper agitation is very important throughout color processing, but it is especially critical during the initial development step. Since the agitation technique can vary from one particular color process to another, you must study in detail the instruction supplied with the materials. *Follow the recommmendations to the letter.*

You can get simplified, uniform agitation by using an intermittent, gaseous-burst agitation system. In this system, bubbles released from the bottom of the processing tank rise to the surface at random, agitating the solutions. Use nitrogen gas with the developers to keep from oxidizing the developing agents. Since the other solutions don't have the oxidation problem, you can use nitrogen gas or oil-free compressed air for them. Although the gaseous-burst systems are normally designed primarily for color processing, you can also use them for black-and-white processing if they are available.

Exercises (302):

1. What are the probable results if you let solution temperatures get too hot?

2. How is the temperature normally controlled in processing color material?

3. What is one of the best ways to get simplified, uniform agitation during color processing?

303. Name and distinguish among the steps in processing reversal or negative/positive color materials, and state which emulsion layer is affected in given situations.

Processing Film. In general, as far as processing is concerned, color films can be placed into two categories—reversal and negative/positive. There are processing similarities and differences. Let us take a more detailed look at the processing steps as they are performed in a processor.

Reversal. In the system shown in figure 2-23, reversal processing has five major steps: first development, reexposure, color development, bleach, and fix. These are basic steps only. Each specific film has certain additions to the process in accordance with the characteristics of its emulsion. Therefore, the tank setup must be compatible with the film you process.

Before processing, you must, of course, expose the film in a camera or in a printer to form a latent image in one or more of the three emulsion layers. The film is now immersed in a developer. This development produces a black-and-white image in the color film that, theoretically, is usuable as such. The image is, of course, a negative image. In black-and-white film, the fixing bath is next. In reversal color, you either reexpose the film to white light at this point or subject it to a color developer containing a chemical reversal agent later. Thus, if you reexpose it, you have a negative black-and-white silver image and a positive latent image. Now, you again develop the film, but in a color developer this time. After color development, the film has a negative silver image, a positive silver image, and a positive color dye image. The colored dyes formed during

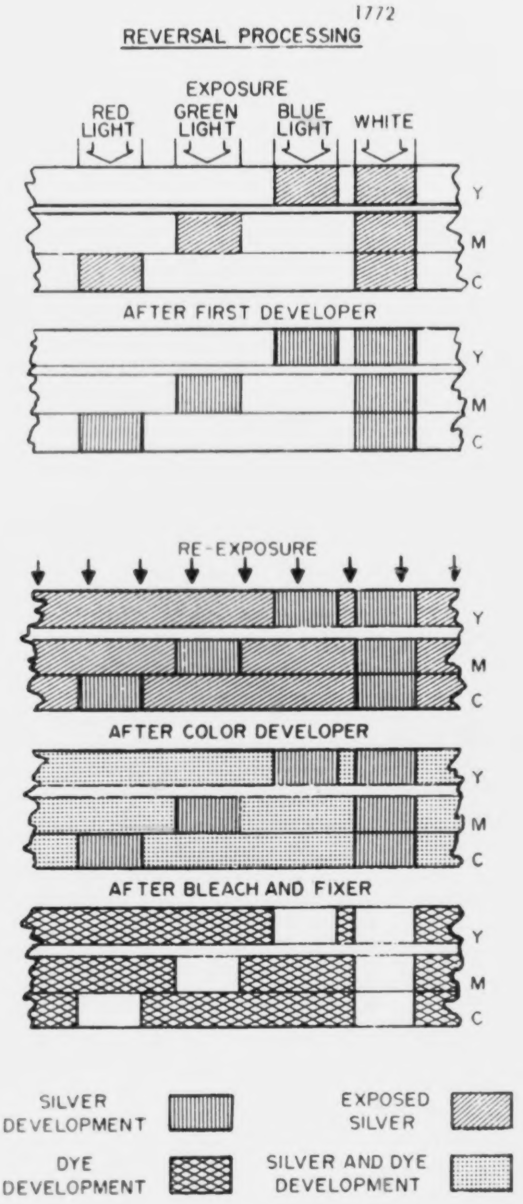

Figure 2-23. Reversal processing.

color development are in proportion to the formation of the positive silver image. The next bath is the bleach, which bleaches out the silver images, leaving the positive dye image and some residual silver halides. The residual halides are removed by fixing and washing.

This process is often referred to as the incorporated coupler process. Dye images are formed during the color development by the reaction of couplers (incorporated with the emulsion) with the color developing agents in the color developing solution. This is the process used for such film as Fujichrome and Ektachrome.

Negative/positive. In this system of color processing, three major processing steps are necessary. Note that the outstanding difference between this and reversal processing is that there is only one development. As an interesting sidelight, you could get a similar color image by skipping the first development in reversal processing and starting instead with color development. Because the film is not designed for such processing chemistry, an inferior image results. As shown in figure 2-24, the major steps of the negative/positive process are *color development, bleach,* and *fix*. Again, these are only basic steps. Depending on the emulsion, you'll need more solutions—primarily water rinse and wash baths. Since the process produces a negative, the illustration also includes printing and processing the print.

In this system, the negative material is first exposed in a camera or a negative (internegative) is exposed from a positive on a printer, forming a latent image in the three emulsions. After exposure, the film is immersed in a color developer. Two images are formed in this solution—a negative silver image and negative dye image. Since two different images can't be tolerated, one must be removed. As in the reversal process, the bleach bath removes the silver image. Now the film passes through a fixing bath to remove the residual silver halides. The result is a negative color dye image. Because this is a negative color, it must be printed onto a print material to get the positive color film for viewing purposes.

We have mainly kept our discussion to the major steps in processing color film, since the procedures for specific films change frequently. You should always refer to the most current instructions from the film manufacturer. As the art of photography progresses, emulsion, time in solution requirements, chemical formulas, etc. change. The processing sequences here are intended only to acquaint you with the general procedure. You should not use them as an exact guide.

Exercises (303):

1. What are the five major steps of color reversal processing?

2. What is the action of the first developer in the reversal color process? What kind of image does it produce?

3. During reversal processing, the film is accidentally exposed to a red safelight. What color dye will be produced by this exposure? (Refer to fig. 2-22.)

4. What are the major steps of the negative/positive color development process?

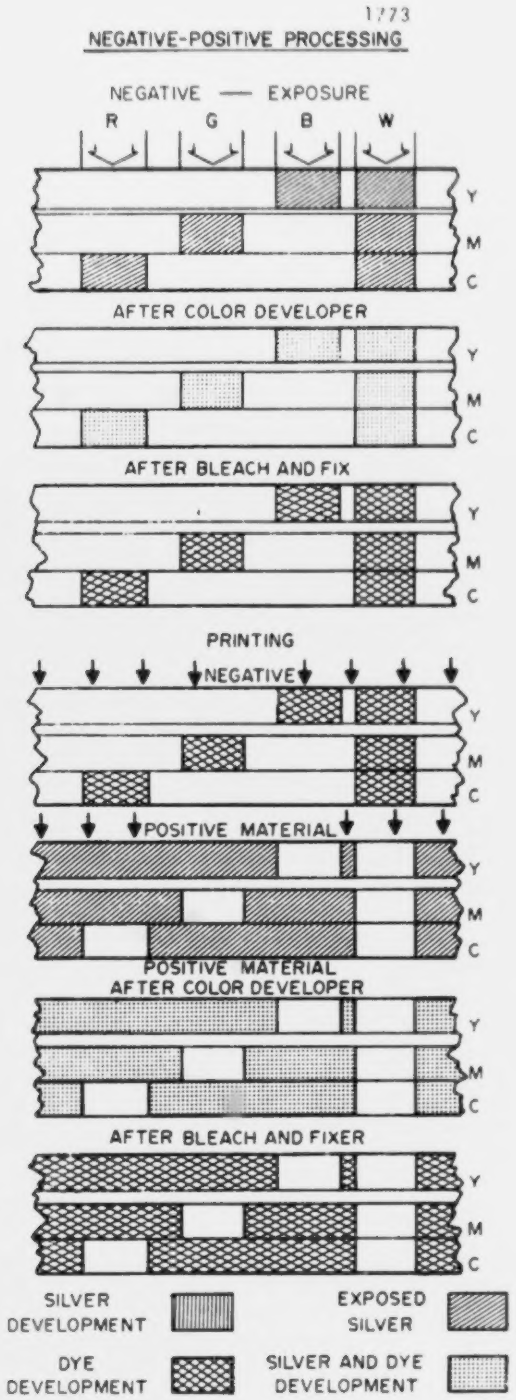
1773
NEGATIVE-POSITIVE PROCESSING
NEGATIVE — EXPOSURE
R
G
B
W
Y
M
C
AFTER COLOR DEVELOPER
AFTER BLEACH AND FIX
PRINTING
NEGATIVE
POSITIVE MATERIAL
POSITIVE MATERIAL AFTER COLOR DEVELOPER
AFTER BLEACH AND FIXER
SILVER DEVELOPMENT
EXPOSED SILVER
DYE DEVELOPMENT
SILVER AND DYE DEVELOPMENT

Figure 2-24. Negative/positive processing.

5. What images are in the film in the negative/positive process after color development?

6. Which emulsion layers are affected in each of these situations?

   a. Reversal film exposed to white light.

   b. Reexposure to reversal film originally exposed to a green subject.

   c. The metallic silver is bleached out of which layers when the film is exposed to yellow light?

304. State how to handle and store color chemicals safely.

Handling Color Chemicals. You have already learned many safety procedures. There are a few other important safety procedures to observe in any kind of processing situation, especially color processing. Let's look at some major precautions that apply to color chemicals and solutions. Be sure you abide by the caution markings on chemical containers. *These warnings are not to be treated lightly.* Some color processing chemicals may only inflame the skin after prolonged exposure, but others can be quite dangerous if they are mishandled.

Contact prevention. The best insurance against problems caused by chemicals is a laboratory and personal program of contact prevention. Many problems stem from the fact that you handle fairly large quantities of hazardous liquids, solvents, and solids. Even in small quantities, some of these are hazardous. Here we'll just list general precautions; your lab has many other, more specific ones. You will find that one of the more effective preventive measures is cleanliness.

a. Keep working areas clean and free from spilled solutions.

b. Wear rubber gloves, protective clothing, and tight-fitting goggles—especially when you're handling large quantities of liquids or any hazardous liquids.

c. Dispense liquids from drums or carboys with mechanical pumps or metering devices.

d. Use bottle tilters or inclinator cradles to pour liquids from carboys.

e. Flush and dry the outside of acid bottles before opening them.

f. Take care in opening containers, and never leave them open.

g. Do not carry concentrated acids, alkalies, or irritants in open containers.

h. Store large hazardous liquid containers on or near the floor.

i. Store flammable solvents in approved containers and away from ignition sources. Store them at electrical ground potential by using a grounding wire. Observe "no smoking" regulations.

j. Do not breathe (or contact) vapor from solvents such as formaldehyde, ethylene chloride, chloroform, and benzyl alcohol. Provide forced air ventilation as required—for example, over the tanks of processing machines or other areas where these vapors exist.

k. Never pipette small quantities of any hazardous liquids by mouth. Use a rubber bulb or aspirator pump.

l. Always add acid to water, never water to acid.

m. Know the location of emergency body and eye showers and how and when to use them.

The principles of *handling solids* safely are basically the same as those of handling liquids and solvents safely. That is, you should avoid skin contact and inhalation. Keep chemicals off the skin, out of the eyes, out of the lungs, and out of the stomach. You achieve such avoidance largely through personal protective measures, mechanical handling, proper storage and transport, use of ventilation hoods, and clothing and area cleanliness. Do all bulk weighing and container-to-container transfer under a vented weighing hood so that chemical dust is removed before it can fall on your clothing or be inhaled. Keep the area clean, wear gloves and goggles, and change clothing frequently. Clothing cuffs catch chemical dust, and they're the most frequent cause of difficulty.

Problem-causing color chemicals. Even if you are not concerned with mixing up large quantities of color processing chemicals, there is still a good chance of contact with them. If you get color developer, bleach, or stabilizer on your hands, immediately wash your hands. If your hands are chapped or cut or if the skin is sensitive for some other reason, the chemicals can penetrate faster and compound the problem.

Color developers are especially active skin sensitizers and can cause dermatitis (skin inflammation) for practically all those who handle them carelessly. The formaldehyde in a stabilizing bath and the potassium dichromate in a bleach bath are also chemicals that cause dermatitis. We don't know how much chemical contact it takes to produce skin hypersensitivity. The amount varies with different people, so avoid *all* contact as much as possible. When you do contact these solutions, wash as soon as possible. Here are some major factors leading to skin inflammation:

a. Frequency and extent of skin contact are the most important causes.

b. Concentrated forms of the chemical (or simultaneous contact with several chemicals) may hasten the effects.

c. Duration of the contact has a pronounced effect. The sooner the chemical is removed, the less the chance of developing dermatitis.

d. A past history or dermatitis of chemical allergy should make you especially cautious of exposure.

e. Previous injuries to the skin can speed the appearance of dermatitis.

Once again, the best cure for dermatitis is an effective prevention program. Learn to recognize the symptoms, if they appear. It is especially important for you to watch your hands and wrists. If any itching, burning, redness, or swelling occurs around your nails or between your fingers, see a doctor as soon as possible. *Do not continue working and do not try to doctor yourself.*

Storing Solutions. The manufacturer's processing kits do not require special storage consideration because the chemicals are in cans. Any reasonable storage conditions should prove satisfactory. This situation changes, however, after you put the chemicals into solution. When the chemicals are properly mixed (in the same rotation they're used, not excessively aerated, in the proper amount, and uncontaminated by other solutions), there are still a few precautions you must take.

For best results, all solutions should be freshly mixed and immediately used. Of course, they should also be brought to the correct temperature. Most unused solutions that are made up may be kept up to 2 weeks if they are stored in full, well-stoppered bottles. Bottles should be full, because any airspace at the top permits excessive oxidation.

Bottles are ideal for storing solutions, but many photographic laboratories with high production rates mix large quantities that make bottles impractical. These labs generally use the open-type tanks so that their solutions can be kept in the tank. A possible exception is the bleach, which should not be kept in contact with air. One of the best ways to cut down on oxidation is to put floating lids on the tanks. These can be paraffin-coated pieces of wood cut to the right size. When the tanks are not in use, the lids float on top of the solution to cut off air contact.

Regardless of the type of storage conditions, discard partially used solutions within about 1 week. If you try to save, you lose in the long run, because old solutions produce offcolor transparencies. Rather than worry about discarding old solutions, arrange an exposing session that gives you enough transparencies for the solutions made up. This lets you process a maximum of film at one time before you must discard the chemicals. On the other hand, don't save exposed, unprocessed film long enough to cause color streaks or a shift in the color balance. This damage varies according to film storage conditions. You *can* process color film partially if you can't do the whole job at one time. This eliminates the problems and difficulties of keeping exposed, unprocessed film. You just put the film through the first developer and a stop bath, then dry it in subdued light. At a later date, the balance of the processing can be completed. Be sure to check the manufacturer's recommendations before you try this. The improper storage or the unwise use of old solutions can cause offcolor transparencies.

Exercises (304):

1. What is the best way to avoid problems in handling the processing chemicals?

2. How should you store flammable solvents?

3. How should you draw small quantities of hazardous liquids from a container?

4. What are some typical hazardous solvents?

5. What safety precautions should you take in weighing bulk chemical powders?

6. What are the major causes of skin inflammation from handling chemicals, and what color processing chemicals are especially active skin sensitizers?

7. How should you store color processing solutions?

305. Identify the cause of color material processing defects, and state the limitations on the use of safelights during processing.

Processing Defects. You know that the light source or lighting conditions can cause a shift in color balance and render untrue colors. You also know that the same type of distortion can come from improper processing. Before you try to find a processing error, be sure to consider the possibility that it may have been caused during exposure. For example, if you use a yellow filter to expose color, you get a transparency with an overall yellow cast. Obviously, this is not due to poor processing, so be sure you eliminate all other possibilities before you blame the defect on processing.

Many common defects are not covered here, since their cause is self-evident. Scratches, fingerprints, and abrasions are easily traced. Your experience in black-and-white processing pays off quickly in checking such blemishes. Color emulsions are extremely soft and easily damaged, so you must take extra care in handling them. Regardless of these difficulties, a good lab technician can readily make the transition to color photography. The main consideration is to follow the manufacturer's recommedations right down to the smallest detail. If these directions are carefully followed, there should be no need to check tables of processing errors. Do the job right in the first place, and the majority of your problems will be nonexistent.

As in black-and-white processing, one of the most common faults is fogging. Usually fog is noticeable in color photography as a washed-out appearance of the colors. If the margins of a transparency are clear (remember this is a reversal process), the film was probably fogged in the camera. If the fog is general, the fogging was probably done during processing. Light leaks in the laboratory must be avoided at all times. Even if you are processing film at night, guard your laboratory from light. It may be dark outside, but the headlights from one automobile can suddenly undo much good work.

The use of a safelight can also cause fog. Color film must be considered as a panchromatic emulsion; therefore, safelights cannot be considered safe. A safelight produces essentially the same result as accidental use of a colored filter during exposure. The only exception to this is that a Wratten No. 10 safelight with a 10-watt bulb may be used as indirect lighting, at least 4 feet from the film. This is not recommended, because there's still a chance of ruining your transparency, and the light is so dim it probably won't do you much good.

Exercises (305):

1. You examine a color transparency and find that the border on one side is clear and the colors in the immediate area are washed out. What is the probable cause of this defect?

2. You shouldn't use a safelight when you process color film, but if you have to use one, how can you do it?

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Black-and-White and Color Reproduction Photography

THE TERM "copying," as used in photography, means the photographic reproduction of another photograph, drawing, photomap, mosaic, chart, or similar flat-plane object. Photographic reproduction is one of the most versatile of the copy methods. This type of reproduction is a photographic function, and specific techniques must be applied to remove the guess work and to minimize or eliminate mistakes in exposure, lighting, film, and developing.

Every picture you see in a newspaper, book, or magazine has been copied at least once. Banks make photographic records of checks received. Entire libraries are copied on film that occupies a fraction of the space required for the books. Copying is thus of great importance. To be successful at copying requires careful work. The problem of copying is complicated by the great variation in the nature of the originals to be reproduced and by the varied working conditions.

Ratio, scale, bellows extension, and exposure become additional factors peculiar to copy requirements. Laboratory work orders may request various types of copy reproductions. The percentage of reduction may be listed as 50 percent, which indicates a ratio of 1:2 or, simply stated, half size. When photomaps or mosaics are to be copied, they have a representative fraction to express scale. For example: An original has 1/6000 scale to be reduced to 1/18000 scale. This would be a 1:3 ratio.

In this chapter, we will discuss copying black-and-white and color continuous tone prints, duplicating transparency material, getting proper lighting ratios, making scale change provisions, calculating exposures, and compensating for increased bellows extension.

3-1. Types of Originals

Subjects to be copied are broadly categorized as either reflective (opaque) or transparent material. Reflective subjects, like photographs, mosaics, and maps, are very common copy subjects. You can get good copies only with proper lighting, camera operation, filter selection, exposure, and appropriate film and developer combination.

306. State how we copy different types of originals.

Reflective Subjects. A reflective subject is one that is opaque. We view it by reflected light, while we view color slides or viewgraphs by transmitted light. Examples of reflective subjects are a printed page, a black-and-white or color print, and line drawing.

Black-and-White Line Originals. Various documents and subjects you might have to copy include such things as maps printed in black-and-white, musical scores for Air Force band members, and published procedures (such as processing instructions for a particular machine) to be used as training aids. You may occasionally copy letters, such as letters of commendation, to be distributed among various personnel at your base.

Generally speaking, a line original has but two tones, black (or a dark shade of gray) and white (or a very light shade of gray). As far as contrast is concerned, these two tones should be separated as much as possible. The net result is high contrast on the negative; and when this is combined with printing on a high-contrast paper, the high contrast of the negative is maintained. Remember that, under these high-contrast conditions, film latitude is very low, and the exposure must be critical. If you miss the exposure, you are taking a chance on filling in or obliterating fine lines on the material. To avoid this, you should allow ample exposure, but not overexposure, on the film.

If the black-and-white material is printed on just one side, you can back it with white paper to increase the contrast, especially if the original was printed on rather thin paper. (Without backing, the dark color of the easel may shine through.) If the material is printed on both sides (say, a page from a magazine), the ink from the reverse side may show through. In such a case, it's a good idea to back the original with black paper.

Colored Line Originals. In general, copying line-type originals that have been printed in color is much the same as copying black-and-white material. Among the colored line subjects you might have to copy are maps different terrain features printed in different colors, drawings printed in colored ink to identify various mechanical features, and blueprints. The usual problem is to get the greatest contrast between the line and the background materials. Typically, it is best to use panchromatic film for this type of copying, since you'll often need to use filters to increase the contrast. For example, when you copy a blueprint, you can get maximum contrast by using a red filter to make the blue background appear clear on the negative.

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Black-and-White, Continuous Tone Originals. The most common black-and-white, continuous tone original that you'll have to copy will undoubtedly be a photographic print. The ultimate in a good copy negative made from such a print should closely resemble the original negative. It should have the same gradation in tones as the original. Accurate rendition of this type of original takes a film with a medium contrast as well as the correct exposure and development. Obviously, if you underexpose a negative in a camera, you lose shadow detail: the same is true in copying. By the same reasoning, overexposure in either situation causes a blocking of highlight detail.

Color Continuous Tone. Typically, you can copy color continuous subjects much the same way you would photograph the original subject; i.e., use a panchromatic film of moderate contrast and an appropriate filter. By manipulating development time, you can control the contrast. You can use a correction filter to balance the color rendition of the film so that it closely matches human eye sensitivity (orthochromatic rendition), or use a contrast filter to accent or to eliminate contrast between certain colors.

Exercises (306):

1. How can you increase the contrast of a black-and-white line original printed on one side of thin paper before you copy it?

2. What color filter will produce maximum contrast in copying a blueprint?

3. Why is exposure critical in using high-contrast film to copy high-contrast subjects?

4. What must you watch for in copying black-and-white continuous tone originals?

5. What must you watch for in copying color continuous tone originals?

3-2. Copy Techniques

There are many photographic cameras that can be used for doing copy work. These range from the simple view camera to sophisticated copy camera systems, complete with lighting equipment, magnification and reduction scales, etc. with the camera being but a part of the complete system. The purpose of this section is to acquaint you with some of the techniques that you can use for copy work, using simple as well as complex equipment. We'll discuss copying with a view camera and on a conventional copy system, lighting, copying to scale, filters, and how to calculate exposure for copy work. Once you are familiar with these techniques, you will be able to adapt easily to any copy system that you may have to use.

307. State how to use copy camera systems and lighting.

Copying With a View Camera. Copy work can be done with almost any type of professional still camera. However, copying differs from conventional photography primarily in two respects. First, the subject has only one plane. It has length and width, but does not have appreciable depth. Second, it introduces the factor of reproduction scale, which makes preparation a little more detailed and exacting than conventional photography. Some subjects will be copied to a 1:1 scale (same size), while others may be made larger or smaller than the original you are copying.

Basic requirements for a camera that's to be used for copy work are through-the-lens viewing and focusing, and the ability to produce images the same size or larger than the item being copied. Let's see how the simple view camera adapts to copy work. The basic features of a view camera that make it suitable for copy work are ground glass focusing and viewing, long bellows to permit at least 1:1 reproduction, movable front and back standards to control image size and focusing, and an apochromatic lens (also known as a process lens). A process lens is one that has been corrected to focus all colors on the same plane and to reproduce them in their relative brightness. A process lens is valuable for any type of copy work, but it's essential for copying colored-copy subjects. Most modern lenses for professional cameras are color corrected, but not all of them are anastigmat lenses. An anastigmat lens is one that is fully corrected for distortion. Lenses designed for copy work are anastigmat for working at the close distances of copy work. If a camera's only lens isn't fully corrected for distortion, the camera may not work as a copy camera.

To use a view camera for copy work you will need to set it up properly. (1) Select a sturdy tripod and mount the camera on it, being sure the legs are set to hold the camera level. Some cameras have built-in bubble levels to help you get the camera level. (2) Most view cameras have full distortion controls, so be sure that they are all placed in the neutral position. (3) You will need a copy board or easel to hold your copy subject. This can be as simple as a bare wall somewhere in the lab or a sheet of fiberboard mounted on the wall. Fiberboard works well, because it is soft enough for you to use thumbtacks to hold the copy subject in place. (4) Center your copy subject upside down on the copyboard. Placement should be high enough so that it is comfortable for you when you are composing the image in the camera. Hold the copy as flat as possible on the board, using thumbtacks or masking tape. Be careful not to damage the copy in any way. They are often one-of-a-kind and not replaceable. Don't push thumb tacks through the original; just stick them into the copyboard, letting the tack heads hold the subject in place. Four thumbtacks are usually enough if you place one at each corner. If you use masking tape, tape the original only at the corners, and be careful not to tear it when you remove the tape after copying.

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One of the most important steps in copy work is aligning the camera to the copy subject in both the vertical and horizontal planes. In other words, you must make certain the camera is parallel with the subject. If this is not done you may end up with a distorted image. Lack of parallelism can give your copy image a "keystone," or trapezoidal, effect. Both the front and the rear camera standards must be parallel with each other and parallel with the subject. Once you've got them parallel, align the camera from side to side with the subject.

Now let's talk about composing the image. The distance from the rear standard (ground glass) to the copy subject determines the image size, and the distance from the lens to the ground glass determines focus. To compose your image, move the camera-tripod combination forward or backward while viewing the image on the ground glass and focusing with the front standard. When you get the approximate image size you need, make your fine image size adjustments by moving the rear standard on the camera. Although you *can* focus the image using the rear standard, you should do it with the front standard, because any movement of the rear standard also changes the image size. Fill up the ground glass with the image, but be careful not to crop out any part of the copy subject unless you're asked to. When you copy a print with borders, include part of the print borders in the image to be sure you haven't cropped out any of the copy work.

Copy Camera Systems. A copy camera is one that is designed exclusively for copy work and serves no other function. A big advantage of a copy camera is that it eliminates many of the setup procedures that align a conventional camera to the copy subject. This is because a copy camera is a system. A typical copy camera system consists of a rigid rail or track, with a specially designed view camera mounted on one end of the track and a vertical copy easel on the other end. The camera is movable on the track, while the copy easel usually is not. All the problems of parallelism are eliminated, because the camera is permanently maintained in parallel with the copy easel on both the vertical and horizontal planes. To enlarge or reduce the subject image, you simply move the camera forward or backward on its track. Compare figures 3-1 and 3-2 and notice the similarities between these two copy camera systems. Both cameras are similar in design and almost interchangeable in application. Each has movable front and rear camera standards; ground glass focusing; attached, swinging lights; long bellows; aligned copy easel; and a fully corrected lens. The differences between the two models are format and easel size, light sources, and positioning of controls. A big difference is the type of film stage used. The camera shown in figure 3-1 uses film holders and can be used in normal room lighting, whereas the camera shown in figure 3-2 has a vacuum back to hold the film on the film stage during exposure. Vacuum-back copy cameras are "split-room" or through-the-wall cameras. The ground glass/film stage is in a darkroom, and no lights or safelights must be used during the exposure step. Also, the camera's rear standard is not movable, so the easel on this type of camera travels backward or forward on the track to adjust image size. Let's first discuss the common procedures for the two models, then "focus" on the operation of the one shown in figure 3-1. General procedures for setting up a copy camera are:

a. Loading the copyboard.

(1) Check to see that the original material and the copyboard are free of lint, dust, or other foreign matter.

(2) Load the original upside down in the center of the copyboard.

b. Scale and focus.

(1) Determine and position the copyboard and bellows for correct scale (size) and focus. Fine focusing must be done by viewing through the ground glass.

(2) Position the lights for even illumination. Check for reflections through the ground glass. Reposition the lights as necessary.

c. Exposure. Determine exposure and set the timer and f/stop to the correct settings. Where possible, set the lens at its critical aperture. (The aperture that renders the sharpest image.) Normally, the critical aperture is two or three stops from wide open, i.e., an f/4.5 lens is usually sharpest at about f/8.

NOTE: To determine proper exposure, you should make a series of test exposures with small 2-inch strips of the film you are using. Keep the f/stop the same and make a series of exposures in increasing increments of 5 seconds; i.e., 5, 10, 15, 20, and 25 seconds.

d. Film loading and exposing.

(1) Position the film so that the emulsion faces the subject during the exposure. (Many copy cameras are set up so that the film loading/exposure section is in a darkroom and the copyboard is in a lighted workroom.)

(2) Start timer and expose. (Most copy cameras are equipped so that when the timer is started the shutter diaphragm automatically opens. Most copy exposures are quite long, ranging up to a minute.)

(3) After the exposure is completed, remove the film and process.

CAUTION: In operating any copy camera, don't force any component to move. If any part does not move freely, check the camera carefully to find the cause. If you can't find the cause, tell your supervisor or repair personnel.

Sometimes you'll have to make copies outdoors by available natural light. In such cases, don't use direct sunlight. Because of its eveness, the indirect lighting in a shaded area is much more desirable. Bounce lighting is sometimes used in copying when the light intensity is too high or when you want flat lighting. You can position the lights so that light will bounce off either the ceiling or walls to illuminate the copy subject.

Now let's zero in on the "Princeton" Model 17 (fig. 3-1), which is used in the horizontal position for copying continuous tone or line originals or transparencies, in black-and-white or color work.

To copy transparencies, you replace the opaque copyboard insert with a special mask that is essentially a black copyboard with a rectangular hole in it. You place the transparency over the hole and hold it in place by clips. Then you insert a special opal glass in the back side of the copyboard and swing the copy lights around on their arms to the back of the copyboard and aim them through the opal glass. This way, the transparency is illuminated by transmitted light. When you're using back-lighting, make sure you don't place the light close enough to shatter the opal glass.

In the vertical position, the camera is used to photograph exploded views, solid objects, printed circuits, and flat copy. The same base is used to support the camera in both

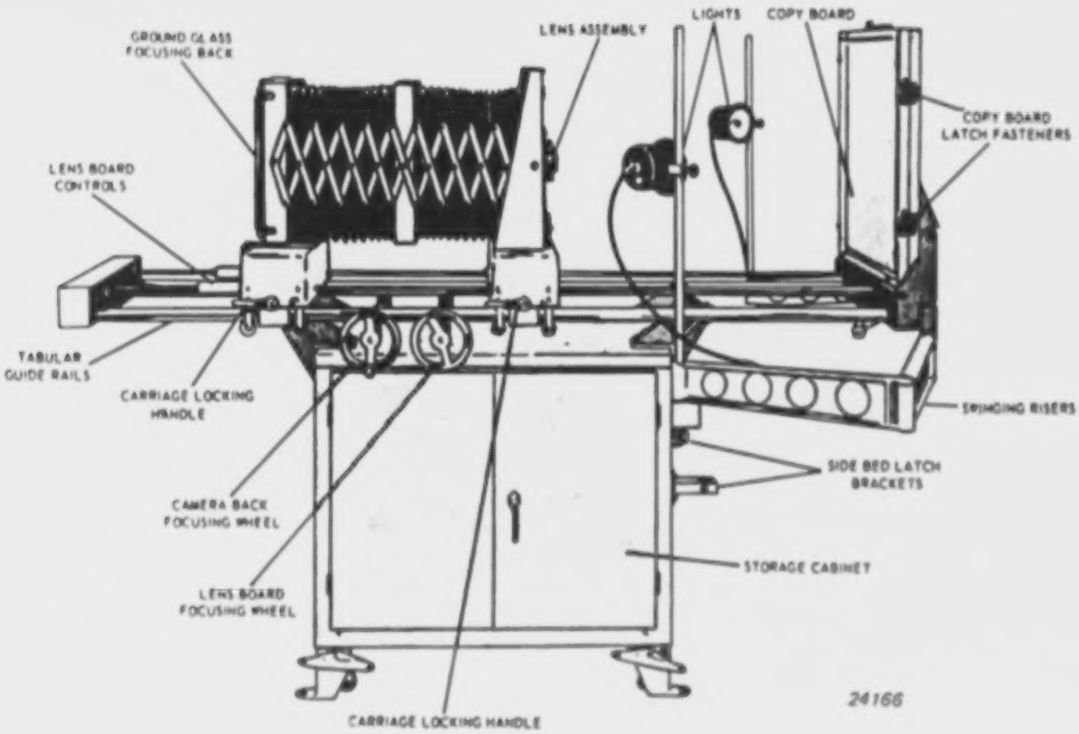
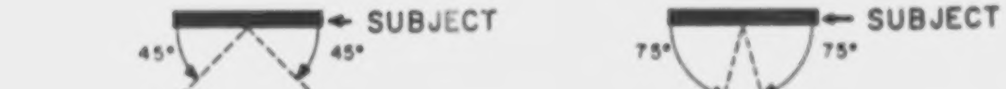

GROUND GLASS FOCUSING BACK
LENS ASSEMBLY
LIGHTS
COPY BOARD
COPY BOARD LATCH FASTENERS
LENS BOARD CONTROLS
TABULAR GUIDE RAILS
CARRIAGE LOCKING HANDLE
SWINGING RISERS
SIDE BED LATCH BRACKETS
CAMERA BACK FOCUSING WHEEL
STORAGE CABINET
LENS BOARD FOCUSING WHEEL
CARRIAGE LOCKING HANDLE
24166

Figure 3-1. Princeton Model 17 copy camera.


SUBJECT
45°
45°
LIGHT
LIGHT
SUBJECT
75°
75°
LIGHT
LIGHT
24165

A. SMOOTH SURFACES

B. ROUGH SURFACES

Figure 3-2. Copy camera NuArc Model SST 1418.

positions. To convert the camera from horizontal to vertical, you just unlatch it pivot it, and latch it back.

Major components. The camera assembly consists of a lens carriage, back carriage, oversized bellows, camera back, adjustable light risers, and copyboard. All components are attached to two tubular guide rails, which extend the full length of the camera assembly. Control wheels on both the lens and back carriages provide precise movements of either lens or film positions along the tubular guide rails. A lockdown lever gives you positive position control.

Lighting Methods. The basic requirement for lighting copy work is that the lighting be even. In conventional photography you will have to work with various lighting ratios to get the effect you want. In copy work, however, you are only interested in a 1:1 lighting ratio. Without even lighting your copy negatives will have uneven density, and it will be very difficult if not impossible to make uniform prints from them. Two light sources are usually best, with one light on each side of the copy subject. The light spread from the two sources should overlap completely to give you even lighting and eliminate shadows.

Front lighting. The simplest type of copy lighting—and often the most efficient—is photoflood lamps in reflectors on movable light stands. The angle at which your light sources strike the copy subject is very important. The actual lighting angle you should use depends on the reflective properties of your copy subject. In copying smooth, glossy surfaces such as a glossy print, you will have a problem with reflections if the lights aren't at the right angle to the copy subject. You can get the best illumination of glossy subjects with the least reflections when your lights are at a 45° angle to the subject (see part A of fig. 3-3.)

When you're copying matte or rough textured subjects, move your lights until they are nearly parallel to the copy surface (part B of fig. 3-3). An angle of about 75° to the subject usually works best for rough surfaces, because it minimizes texture and retains subject detail.

After placing your lights, check the image on the ground glass and reposition the lights as necessary to eliminate reflections. This is very important because unwanted reflections will mask or obliterate detail in the copy image. For even lighting, both lights should be of the same intensity, distance, and angle in relation to the copy subject. Uneven lighting is hard to detect, but you can check for evenness by comparing incident light readings from the center with readings you take at the corners of the subject.

Exercises (307):

1. What is a primary difference between copy work and conventional photography?

2. List some capabilities of a camera that's suitable for copy work.

3. For what copy subjects is an apochromatic lens essential?

4. Why must the camera you use to copy be aligned with the subject?

5. What purpose does the movable rear standard on a copy camera serve?

6. To copy a glossy print, at what angle to the subject should you place the copy lights?

7. In doing a copy job, you think you might be getting uneven illumination. How can you check?

8. Why is angle lighting important in copying rough surface materials?

9. What type of outdoor lighting can be used effectively to light copy subjects?

10. What is the difference between the film stages of the copy cameras shown in figures 3-1 and 3-2?

11. If you're copying a transparency, what lighting will you use and how will you do it?

308. Solve a series of scale change problems.

Copying to Scale. The scale of a reproduction is the ratio between any linear dimension of the copy and the related dimension of the original. For example, if a 4 x 5 picture is reproduced at half scale, the reproduced dimensions are 2 x 2½ inches.

A considerable portion of your copy photography will include copying mosaics to a specific scale. To enlarge, you must have a bellows extension that's more than twice the focal length of the lens. The focal length of the lens (FL), the bellows extension (BE), and the distance from the subject to the lens (SD) are all interrelated. These relationships can be found easily with two simple formulas:

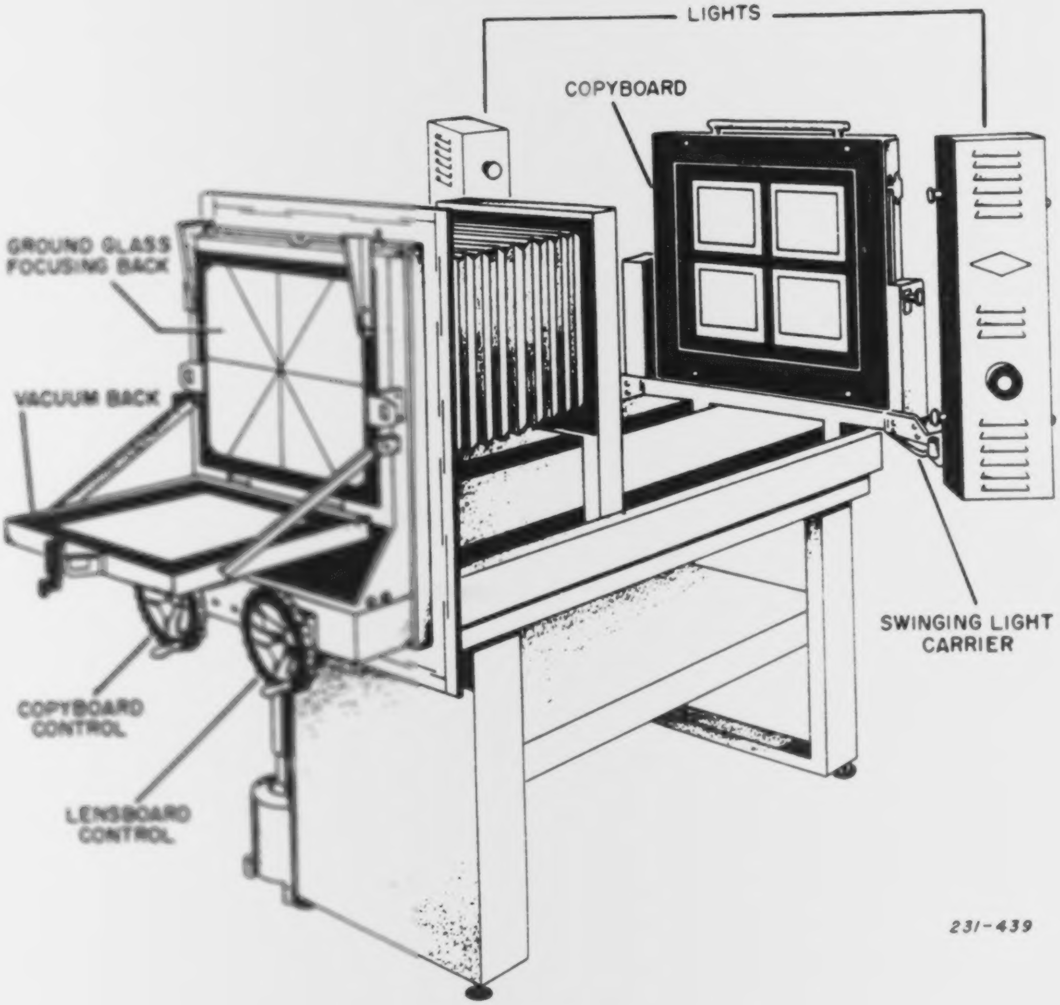


Figure 3–3. Lighting angles.

Bellows extension = FL × (scale + 1)
Subject distance = BE ÷ scale

Now let's use these formulas to solve two sample problems. First let's find the bellows extension and subject distance for a 12-inch (305-mm) focal length lens at two different scales. If the scale is 1-to-2, or 1/2 size,

Bellows extension = 12 × (1/2 + 1) = 18 inches
Subject distance = 18 ÷ 1/2 = 36 inches

If the scale is 1-to-1,

Bellows extension = 12 × (1 + 1) = 24 inches
Subject distance = 24 ÷ 1 = 24 inches

Of course you will need the formula for copying mosaics, since the photographic reproduction of mosaics is needed for mass production or for changing the scale. Often, too, we need several mosaics of the same area. At such times, it is easier and quicker to assemble one mosaic and reproduce it than to assemble more than one mosaic from the original negatives. To copy a mosaic to a different scale, use the formula:

$$\frac{\text{mosaic scale}}{\text{copy scale}} = \frac{\text{distance on mosaic}}{\text{distance on copy}}$$

Again let's apply this formula to a typical case. Let's say we're enlarging a mosaic with a scale of 1 to 10,000 to a scale of 1 to 8,000. A distance of 5 inches (the distance between two roads, for example) on the mosaic will be how many inches on the copy? Let's use the formula:

$$\frac{\frac{1}{10{,}000}}{\frac{1}{8{,}000}} = \frac{5}{X}$$

$$\frac{8{,}000}{10{,}000} = \frac{5}{X}$$

$8X = 50$

$X = 6\frac{1}{4}$ miles between the roads.

Exercises (308):

1. A 300-percent enlargement of a 4 x 5 picture would give you what final dimensions?

2. Suppose a mosaic with a scale of 1 to 20,000 is copied to a scale of 1 to 10,000. A distance of 5 miles on the mosaic is how many miles on the copy?

3. Suppose you are using a 10-inch lens and you are making a 1:3 copy. What will be the bellows extension and subject distance?

4. Assume that you are using a 200-mm focal length lens and you are making a 2:1 copy. What will be the bellows extension and subject distance?

309. Cite and explain relationships of bellows extension and exposure.

Bellows Extension. The f/stop shown on a lens is a ratio between the focal length and the diameter of the aperture. As long as the focal length remains constant the f/stop will be accurate. To get a larger image, we must use extension tubes on 35-mm cameras or extend the flexible bellows of a copy camera. As a general rule, whenever your camera is focused closer than 8 times its focal length, you are dealing with bellows extension. The closest focusing distance of a 50-mm lens is 400 mm. To focus closer and enlarge the image size, you need bellows extension. Whenever the focal length is extended beyond normal focal length, you'll need the inverse square to figure out how much to increase exposure. Since the distance from the lens aperture to the film plane has increased, you've reduced the intensity of the light reaching the film plane.

Let's look at an example of bellows extension becoming an exposure factor. To copy an 8 x 10-inch photograph to the same size (1:1) using a 12-inch lens, you will find that when you get the image the same size as the original you will have a bellows extension of 24 inches, which is twice the focal length of the lens. This extra 12 inches has reduced the light intensity at the film plane to 1/4 of its original intensity. Obviously the reading you get from your exposure meter will result in a severely underexposed negative.

Exercises (309):

1. Why does bellows extension beyond normal focal length affect exposure?

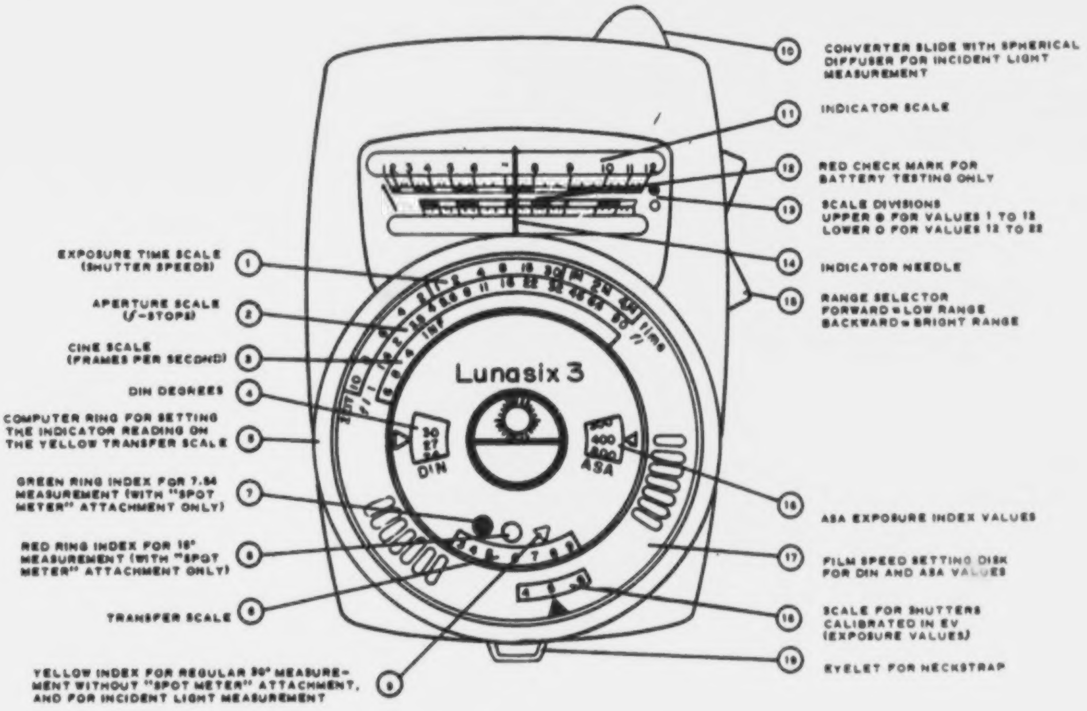

Lunasix 3
DIN
ASA
① EXPOSURE TIME SCALE (SHUTTER SPEEDS)
② APERTURE SCALE (f-STOPS)
③ CINE SCALE (FRAMES PER SECOND)
④ DIN DEGREES
⑤ COMPUTER RING FOR SETTING THE INDICATOR READING ON THE YELLOW TRANSFER SCALE
⑦ GREEN RING INDEX FOR 7.5° MEASUREMENT (WITH "SPOT METER" ATTACHMENT ONLY)
⑧ RED RING INDEX FOR 15° MEASUREMENT (WITH "SPOT METER" ATTACHMENT ONLY)
⑥ TRANSFER SCALE
⑨ YELLOW INDEX FOR REGULAR 30° MEASUREMENT WITHOUT "SPOT METER" ATTACHMENT, AND FOR INCIDENT LIGHT MEASUREMENT
⑩ CONVERTER SLIDE WITH SPHERICAL DIFFUSER FOR INCIDENT LIGHT MEASUREMENT
⑪ INDICATOR SCALE
⑫ RED CHECK MARK FOR BATTERY TESTING ONLY
⑬ SCALE DIVISIONS UPPER ● FOR VALUES 1 TO 12 LOWER ○ FOR VALUES 12 TO 22
⑭ INDICATOR NEEDLE
⑮ RANGE SELECTOR FORWARD = LOW RANGE BACKWARD = BRIGHT RANGE
⑯ ASA EXPOSURE INDEX VALUES
⑰ FILM SPEED SETTING DISK FOR DIN AND ASA VALUES
⑱ SCALE FOR SHUTTERS CALIBRATED IN EV (EXPOSURE VALUES)
⑲ EYELET FOR NECKSTRAP

Figure 3–4. Typical exposure meter.

2. What is the closest focusing distance for a 100-mm lens without introducing bellows extension?

310. Compute procedural elements used for determining proper exposure for copy subjects.

Determining Exposure. There are a number of ways to determine proper exposure for copying. Some are easier than others, but they all get the same result. The method you use is up to you. To find the right exposure for copy subjects, you use the same tools as with other cameras. The only difference is that you compensate for bellows extension.

After setting up your copy subject and getting the image composed to size, the lighting arranged, etc., your final step is to take a meter reading. Use an incident light meter at the subject plane to determine an exposure. Look at the light meter in figure 3-4. Suppose that your exposure is 1/60 second at f/11 using ASA 100 film. Your next step is to find the bellows extension. Keep in mind that you'll need to increase the exposure above the meter reading if the measured bellows extension is larger than the normal focal length of the lens you are using. In this case, you are using a 12-inch lens. Measure the bellows extension from the lens to the film plane. The distance in this case is 24 inches. Now you use this formula to find the exposure adjustment factor:

$$\text{Exposure factor} = \left(\frac{BE}{FL}\right)^2 = \frac{576}{144} = 4$$

The exposure must be increased 4 times, so you can change to any combination of aperture and time that increases exposure by the equivalent of two f/stops. In copy work it is better to change exposure time, so you wind up with a new exposure of 1/15 second at f/11.

Another way to adjust exposure is to change the film speed. Use the formula:

$$\text{Effective Film Speed} = \frac{\text{film ASA}}{\left(\frac{BE}{FL}\right)^2}$$

For example, the film ASA is 100. The quotient of the bellows extension and the focal length is 2. The 2 squared equals 4. Now divide 100 x 4 for a new film speed of 25. It's now a simple matter of taking the exposure with a meter set at the adjusted ASA.

Another way, which doesn't require you to use a formula, is to let your exposure meter do the work by simply considering the f/stops on the meter as focal lengths. Look at figure 3-4 again for this method. Using 1/60 second at f/11 in our previous example, rotate the f/stop dial of your meter so that the f/stop that represents the focal length of the lens you are using is opposite 1/60 second. Using a 12-inch focal length lens, set f/12 opposite 1/60 second. Now read the new exposure time across from the f/stop that represents the bellows extension. In this case the new exposure time will be shown directly opposite f/24. The new exposure time is 1/15 second.

Exercises (310):

1. If the indicated exposure for a copy subject is 1/60 second at f/16, using a focal length of 12-inches and bellows extension of 24-inches, what should the adjusted exposure be?

2. In using an exposure meter to find increased exposure time for bellows extension, what do the f/stops represent?

3. If the exposure reading for a copy subject is f/22 at 2 seconds, what change would give correct exposure with a bellows extension exposure factor of 8?

311. State what filters you should use for typical situations and what would happen if you used the wrong filter.

Filters for Copying. A photographic filter transmits certain colors of light and absorbs others. By modifying the color of light striking the film, the filter affects the final print. Each filter transmits its own color and absorbs all or part of the other colors. For example, a blue filter passes blue light and absorbs red and green. If you photograph a red, green, and blue subject through a blue filter, the resulting negative will be dark (dense) in the blue areas and light (thin) in the red and green areas. A print made from this negative will show the dark and the light areas reversed in density. In other words, in the print a filter lightens its own color and darkens others.

Correction Filters. There are no photographic emulsions that have the same color sensitivity in shades of gray as that of the eye. Generally, films are more sensitive to blue and red than the human eye. Since your eye is more sensitive to green than film is, color correction filters are used to compensate for the difference. The correction filters absorb part of the colors that the film is sensitive to, consequently, the film then produces the colors in shades of gray that correspond in brightness values to the way your eyes sees them. This is called orthochromatic rendition.

A complete set of filters for copying should include three correction filters and five contrast filters. Wratten correction filters are numbered K–2 medium yellow, X–1 light green, and X–2 slightly darker green.

The selection of a correction filter depends on the type of film and the kind of lighting. For instance, with panchromatic type B film, you get true color rendition with the K–2 filter if you make the exposure by daylight; or with the X-1 filter if you make the exposure by tungsten light. More specifically, if daylight-type illumination is used, some blue light must be absorbed to produce true-color results. The yellow K-2 filter transmits red and green and is of the proper density to absorb just enough blue to render the desired effect. On the other hand, when you expose by tungsten light, which has a high proportion of red, some red as well as blue must be absorbed. This is best done with the X-1 filter which, being light green, transmits green and absorbs the correct amount of red and blue. The highly red-sensitive panchromatic type C film requires the X-1 in daylight and the X-2 for tungsten illuminations.

Contrast filters. Contrast filters are used in general photography for special effects, but they have considerable application in copy photography. The set of five contrast filters are G-15, deep yellow; A-25, medium red; F-29, deep red; B-58, deep green, and C-5, deep blue. These are strictly Wratten designations.

The last three of these filters are dense enough to absorb completely the other primary colors if the exposure is reasonably accurate. Remember, if a negative is overexposed through a filter, some of the colors that normally would be absorbed will register on the film.

In a colored electrical circuit or hydraulic diagram made without a filter, two or more colors may reproduce as the same shade of gray, destroying the distinction between the circuits or diagrams. Therefore you must use a filter that creates a contrast between colors and renders each color as a different shade of gray.

When you're using a filter, especially a contrast filter, always remember to apply the filter factor when you compute the exposure. With the short exposure latitude of some films used in copying, failure to apply the proper factor produces poor results.

Exercises (311):

1. If you're copying a subject with red, green, and blue objects, how will these colors reproduce on a negative if a dark red filter? is used ?

2. What is the function of a correction filter?

3. In setting up for a copy job, how do you pick a correction filter?

312. Calculate the exposure increase for given filter factors.

Compensating for Filter Factor. Since filters absorb light, you must increase the exposure when you use a filter. How much you increase the exposure depends on the color and density of the filter, the color sensitivity of the film, the color of the light, and the reflective properties of the subject. The exposure increase necessary for each filter is generally given as a filter factor. You can find the specific filter factor for your film-filter combination on the film's data sheet. One way to use these factors is to divide the factor into the exposure index for your film and set the meter to this new figure. For example, with Eastman Kodak Tri-X Pan, rated at ASA 400 and a light-green filter (with a factor of 4), set your meter at 400 divided by 4 or 100. Once you have set the meter at the new exposure index, you can use it as you would normally.

Another way to apply the filter factor is through the f/stop setting. If necessary, you can set the aperture indicator between the f/stops and take care of odd filter factors. Before trying this method, you should become thoroughly familiar with the f/stops and their function in changing exposure. The chart below shows what the filter factor means in relation to f/stops. As you can see, a filter factor of 2 takes only a one-f/stop increase from the basic setting. The number directly below each factor tells you how many f/stops to open the lens for correct exposure.

Filter Factor	1.5	1.7	2	2.5	3	4	5	6	8
Increase f/stop by.	2/3	2/3	1	1⅓	1⅔	2	2⅓	2⅔	3

A third way to compensate for the filter factor is to multiply the exposure time by the filter factor. For example, a basic exposure without a filter is 1/400 at f/16. After installing a filter with a factor of 4, the new exposure would be 1/400 x 4/1 = 1/100 second (using the same f/stop, F/16). Remember, though, filter factors serve only as guides. As you know overexposure can wipe out the filter for many black-and-white films.

Exercises (312):

1. You're is using Tri-X panchromatic film rated at ASA 400 and a yellow filter with a factor of 2. What's your meter exposure setting?

2. You've got an exposure of 1/400 at F/11 without a filter. If you add a filter with a factor of 4 what will your f/stop be?

3-3. Processing and Finishing

Now that you have a properly exposed record of a copy original, your next step is to process the film and finish it, ready for making as many prints as the work request requires. In this section, we discuss film developer combinations and the finishing techniques of opaquing.

313. Select the proper film-developer combination for typical copy originals.

Film and Developer Combinations. The selection of a film-developer combination for copy photography should be governed primarily by the classification of the copy subject and, to a lesser extent, by the printing method to be used. Since the characteristics of film emulsions vary widely, you must know them to choose the film that will give you the best results. Two types of Air Force film are being used in copy work—type V (cut film) and type VII (photomechanical film). These two types are broken down into classes, depending on their use in copy work. We will limit our discussion to type V, classes A and E–1.

Characteristics of Medium-and Low-Contrast Films. Copying continuous-tone subjects takes a film with a much greater tonal range than that of photomechanical film. In the case of colored, continuous-tone subjects, you need a film that is sensitive to all colors. Films with these characteristics normally have a much lower inherent contrast and thus require somewhat different treatment.

Class E–1 film, which is usually called commercial ortho by film manufacturers, is slow. It has fine grain, medium resolving power, and medium contrast. Since it is sensitive only to the blue and green parts of the visible spectrum, it is best suited for subjects without red. For copying, then, you should use class E–1 film for continuous-tone, black-and-white prints. As you can see by the name commercial ortho, this is an orthochromatic emulsion. The grain, resolving power, and contrast of E–1 film make it suitable for copying general commercial-type photography, which demands reproduction of fine detail plus graduations of tone. The developer recommended for class E–1 film is DK–50 (AF#2) or HC–110. For dilution ratios, developing times, and recommended developing temperatures, refer to the manufacturer's data sheet for that particular film.

Class A film is a panchromatic film with medium contrast, moderate speed, fine grain, and good resolving power. Because it is panchromatic, it is sensitive to all colors. This film is most suitable for copying colored, continuous-tone subjects when the colors must be reproduced with the correct rendition. Class A film is also excellent for general indoor and outdoor work when you don't need high-speed film. The recommended developer is DK–50 (AF#2). Remember that your best source of information about any film is the manufacturer's data sheet. Keep a file of these sheets to consult when you are deciding what film-developer combination to use.

Exercises (313):

1. Which type and class of film should you use to copy colored continuous-tone subjects? What developer should you use?

2. What class of film and what developer should you use to copy black-and-white, continuous-tone subjects?

314. Cite basic techniques for spotting and opaquing.

Spotting, in reference to negatives, means eliminating small transparent areas in the emulsion. When these areas are not altered, they appear as black spots in the print. Removing these spots in the print is rather difficult, since each spot must be etched from the print or covered with some opaque spotting medium. In spotting, the object is to make the area white on the print instead of black. The white spot is then easily eliminated by spotting the print. Some of the defects that require spotting are the marks caused by dust, lint, pinholes, small hairs, emulsion defects, and scratches. *Opaquing* is covering an undesirable part of the negative with a light-resistant dye or opaque. When you do this, the blocked portion of the print appears white.

Spotting Technique. Place the negative on the retouching easel, contact printer, or plotting table with its emulsion side toward the glass. Dip the mapping pen in the dye. Using good magnification, lightly touch the spot on the back side of the negative. With care, you can confine the dye to the spot without spreading it over the surrounding area. Use extreme care in keeping the point clean if you have to do fine work quickly. You will notice that the pen point has a tendency to pick up small pieces of gelatin from the negative. Because pinholes are actually small holes in the emulsion, you can't spot them on the emulsion side of the negative. Capillary action draws the dye to the sides of the hole, and the pinhole remains uncovered. At best, a pinhole is very hard to correct on a negative; sometimes you can do it successfully on the negative's base with a dye.

Opaquing Technique. Start by placing the negative on a well-illuminated surface, such as a printer, retouching easel, or plotting table. The negative may be blocked on either side, or both sides if necessary. It is best, however, to block on the base side to keep from scratching the emulsion.

Saturate a cotton swab to about half its length with 1A red dye. Follow the outline of the image, using short, side-to-side strokes. Work slowly, allowing enough time for the gelatin to become saturated with the dye. Experience and practice make it comparatively easy to follow the outline accurately. Use the swab the same way you would use a pencil or crayon. You may have to block on both sides of the negative if the area is very thin and the image quite dense. However, this would be an exceptional case. You can fill in narrow areas with a mapping pen. One common practice is to outline the subject with a mapping pen and block the remainder of the negative with a brush. Normally, we don't completely reverse a background from black to white.

Dye blocking does not crack or flake off the negative. Once it is applied, it is permanent. Errors may be removed by lightly wiping the area with a cotton swab and clean water. If the dye is not completely removed by the water, use a 10 percent solution of sodium sulfite. You can remove all of the dye by soaking the negative in a tray of this solution. With moderate agitation, the red color and the resulting yellow stain both disappear. Wash the negative in running water for 5 minutes and then dry. You can then redo the blocking if you want.

Opaque may also be used for blocking. Although it may have a tendency to crack and flake, it does block completely with one application. Too, you can use it a rather thick consistency, so it doesn't tend to run like the red dye. It is exceptionally good for following along the edges of objects.

Exercises (314):

1. How will spotted or opaqued areas on the negative appear on the print?

2. Pinholes sometimes are spotted successfully on which side of the negative?

3. What agents can you use for opaquing?

4. With what solution can you remove dye?

3-4. Correcting Defects

We can hope that the materials you receive to be copied will be in good condition. Occasionally, though, you'll get soiled, wrinkled, yellowed, or stained prints. It is possible to copy a poor original and make the reproduction better. In this section, we discuss basic techniques for copying defective originals.

315. Specify corrective techniques to eliminate or subdue defects in materials to be copied.

Eliminating Stains. Often black-and-white continuous tone prints that must be copied have stains on them. The most common condition is the overall yellowing of a print that's inherent to aging, but you may get prints with localized red, green, blue, or other colored stains. You can eliminate a transparent stain by using a contrast filter over the lens. A transparent stain is one through which the photographic image can be clearly seen. Opaque stains can't be removed by filtering, because they obscure the photographic image beneath them.

If you're using panchromatic film to copy a continuous tone print with a transparent stain, select a filter the same color as the stain. For example, if the print has a yellow stain, exposing the entire print through a yellow filter should eliminate the stain. The filter receives an even exposure to yellow light, eliminating the yellow stain. To see what effect a filter will have, view the photograph through the filter and use the density that seems to eliminate the stain. For stains that are on dark backgrounds, a filter may not completely absorb the stain. Use a heavy density filter to subdue the stain as much as possible. Make a test exposure with the filter you have selected, remembering to increase the exposure to compensate. The result of your test should tell you whether or not you need to use a denser filter to eliminate the stain.

Copying Yellowed Prints. In contrast with stained prints, copying faded prints differs in several ways. For one thing, if the image has turned yellow with age, you must restore its original brillance. Consequently, you should use a filter that is opposite in color to the faded image. For example, if the image has turned yellowish-brown, you can best copy the print with panchromatic film and a blue filter, but you may find it simpler to use a blue-sensitive film without a filter.

Copying Blueprints. Copying blueprints can be a problem if you don't filter the blue. The background for a blueprint is of course blue. This happens to be the color to which all films are the most sensitive. If you were to copy a blueprint without any filtration, the background would reproduce too light and the information on the blueprint would be blurred because of the tendency for the blue to "blend" into the lines and figures of the blueprint. To eliminate this problem, use a deep-red filter such as a number 25. This filter will absorb most of the blue, resulting in a background density in the negative which, when printed, reproduces the blue in its proper tone.

Other Problems. Very often you may have to copy old photographs that are wrinkled or creased. In the original, these wrinkles or creases generally cause reflections. You can often avoid these reflections by pressing the print under a piece of heavy glass and copying it through the glass.

Ordinarily a badly soiled print should be cleaned before copying, but it's valuable, you should get the best possible reproduction before you try any cleaning. Of course, if damage to the old original is considerable, get the best possible copy; then retouch the resulting print and recopy it. A soiled color print may be very hard to clean because of the nature of the dyes that make up the image. You may find that the best way is to copy the soiled print and then to retouch the print from the copy negative. Then you can copy the retouched print. Stained colored prints can be copied through the appropriate filter. The filter should be darker than the stain color. One problem is that the filter will affect the other colors of the print. To restore proper density and contrast, you have to use increased development or retouching may.

Exercises (315):

1. What color filter can you use to improve the contrast in the reproduction of an old-yellowed photograph?

2. If you had to copy a black-and-white, continuous tone photograph with a localized red transparent stain, what color filter could be used to eliminate the stain?

3. What filtration will faithfully reproduce a blueprint?

4. What technique can be used to copy a wrinkled and creased photograph?

5. What should you do before you try to clean a valuable photograph that is badly soiled?

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Answers for Exercises

CHAPTER 1

Reference:

200 − 1. The distance between two consecutive wave crests.
200 − 2. The color of light.
200 − 3. The number of waves that pass a fixed point in a given unit of time.
200 − 4. As that portion of the total electromagnetic spectrum visible to the human eye.

201 − 1. The rate at which light travels in space.
201 − 2. The density of the medium that it passes through.
201 − 3. The change in direction after light strikes a surface.
201 − 4. The passing of light through a medium.
201 − 5. a. Translucent.
    b. Transparent.
    c. Opaque.
201 − 6. Absorption.
201 − 7. Refraction.

202 − 1. Refraction.
202 − 2. The amount of light allowed to pass through the lens.

203 − 1. Plano-convex, positive.
203 − 2. Plano-concave, negative.
203 − 3. Concavo-convex, negative.
203 − 4. Biconvex, positive.
203 − 5. Convexo-concave, postive.
203 − 6. Biconcave, negative.

204 − 1. a. Short focal length lens.
    b. Long focal length lens.
    c. Long focal length lens.
    d. Short focal length lens.

205 − 1. a. Lens A.
    b. Lens B.
    c. Lens A.
    d. Lens B.
    e. The same.

206 − 1. The ability of a photographic lens or material to form an image of or record fine detail distinguishably.
206 − 2. Because the resolving power of any one variable in a system is very hard to measure. Usually, several variables are used to determine the resolving power of any other variable.
206 − 3. Resolving power, sharpness, graininess, and tone reproduction.
206 − 4. High-altitude aerial photographs.
206 − 5. Acutance.

207 − 1. a. Curvature of field.
    b. Coma.
    c. Flare.
    d. Chromatic aberration.
    e. Astigmatism.

208 − 1. a. 42 mcs.
    b. 13 mcs.
    c. 6 mcs.
    d. 97 mcs.
    e. 40 mcs.
    f. 18 mcs.
    g. 26 mcs.

209 − 1. It keeps the lens at a specific distance from the focal plane.
209 − 2. Body drive assembly.
209 − 3. It uses a vacuum plate to hold the film taut across the magazine rollers at the focal plane.

210 − 1. A vertical camera.
210 − 2. A low altitude, high speed mission.
210 − 3. The special format camera (PAN) uses a rotating prism to continuously expose the image onto the film, creating an overall image with extremely wide angles of view.

211 − 1. It presents an image seen from an unfamiliar point of view and shows a limited field of view.
211 − 2. An aerial photograph taken with the camera axis directed intentionally between the horizontal and vertical.
211 − 3. Trimetrogon photography is used in search reconnaissance. It takes three wide-angle cartographic cameras, one vertical and two obliques. The cameras are positioned to cover horizon to horizon.

212 − 1. Radar beams are transmitted at right angles from the aircraft, giving the radar antennas a look from the sides of the aircraft.
212 − 2. An object radiates infrared energy, the airborne sensor picks up the radiation and focuses it onto an electronic unit. This unit converts the infrared into an electronic signal which is projected onto panchromatic film through a CRT. The film is then processed normally at the completion of the mission.

213 − 1. Emulsification, first digestion (ripening), wash, second digestion (after ripening), emulsion finishing, and coating.
213 − 2. During the ripening step.

214 − 1. To preclude stretching and shrinking.
214 − 2. For personal safety.
214 − 3. To enhance printing.
214 − 4. To prevent deterioration, damage due to moisture, and frilling.

215 − 1. Overcoating.
215 − 2. Overcoating.
215 − 3. Substratum coating.

216 − 1. Panchromatic.
216 − 2. Blue-sensitive.
216 − 3. Infrared.
216 − 4. Orthochromtic.

217 − 1. f/8.
217 − 2. f/11.
217 − 3. f/22.
217 − 4. f/32.

218 − 1. ASA 125.
218 − 2. ASA 100.

219 − 1. Low.
219 − 2. a. Low.
    b. Meduim.
    c. High.

220 − 1. The built-in ability of the film to record scene brightness ranges.
220 − 2. The range of exposures that produce satisfactory negative densities.

221 − 1. As it increases, you'll need more film latitude.
221 − 2. Low.
221 − 3. The ratio of 1:50.

222 − 1. To determine the ability of a film to record fine detail.
222 − 2. No. So many factors influence resolving power that all measurements are, in reality, the resolving power of the system.

223 − 1. Film becomes brittle and stiff, cracks may appear in the emulsion, the film loses speed, and there's greater probability of abrasions and static electricity markings.
223 − 2. Overall fog, increased film speed, and increased contrast.

224 − 1. Fog might be produced, fungus might begin growing, transparent spots might be produced, etc.
224 − 2. Moisture will condense on the film.

225 − 1. The emulsion coated on paper is much thinner.
225 − 2. Reduced latitude and increased image reflectivity.
225 − 3. There's only one correct exposure available.

226 − 1. Glossy, semimatte, and matte.
226 − 2. Double weight, single weight, and light weight.

227 − 1. The speed ratings are relative, not absolute; the new box of paper is slightly more sensitive.
227 − 2. Change to a number 1 paper.

228 − 1. Number 3.
228 − 2. Number 5.

228 – 3. Number 3.
228 – 4. Number 2.

229 – 1. Heat and moisture.
229 – 2. Increased fog, inferior tone reproduction, loss of emulsion sensitivity, shrinkage, distortion, and brittleness.

230 – 1. Since photographic materials packaged for domestic use aren't vaportight and watertight, they might be contaminated by gases or contain moisture.
230 – 2. The material was not allowed time to reach equilibrium with the environmental conditions; therefore, condensation formed on the paper.
231 – 1. The overcoating protects against abrasions, the blue-sensitive emulsion produces yellow dye, the yellow filter absorbs the blue exposing light, the green-sensitive emulsion produces magenta dye, the clear gelatin separates the green and red sensitive emulsions, the red-sensitive emulsion produces cyan dye, the antihalation layer keeps the exposing light from reflecting, and the film base is for support.

232 – 1. It is degraded or out of color balance.
232 – 2. Blue.
232 – 3. Red.
232 – 4. Red.
232 – 5. Blue.

233 – 1. a. Red-sensitive layer.
  b. Blue-sensitive layer.
  c. Green-sensitive layer.
  d. Blue- and green-sensitive layers.
  e. Blue- and red-sensitive layers.
  f. Green- and red-sensitive layers.

234 – 1. Too much density.
234 – 2. a. Red.
  b. Blue.
  c. Green.
234 – 3. Overexposure.

235 – 1. Hue.
235 – 2. Chroma.
235 – 3. Value.

236 – 1. Temperature and humidity.
236 – 2. 40 to 50 percent.

237 – 1. Hypo salts remaining in the emulsion.
237 – 2. Accelerated film size changes from the humidity and permanent damage to the film base and emulsion from fungus growth.
237 – 3. A change in color balance and sensitivity.

238 – 1. Solvent, developing agent, preservative, accelerator, and restrainer.
238 – 2. a. Preservative.
  b. Restrainer.
  c. Solvent.
  d. Accelerator.
  e. Developing agent.

239 – 1. To stop development, to prolong the life of the fixing bath, and to prevent the staining of photographic prints.
239 – 2. Water, acid, and hardening.
239 – 3. Preservative.
239 – 4. A buffer.
239 – 5. Silver halide solvent.
239 – 6. Hardener.
239 – 7. Acid too strong either in the stop bath or fixer.

240 – 1. Prehardener, neutralizer, first developer, first stop bath, color developer, second stop bath, bleach, fix, and stabilizer.
240 – 2. Three.

241 – 1. To reduce emulsion swelling, making it more resistant to physical damage during processing.
241 – 2. The amount of prehardening affects the rate at which subsequent solutions will diffuse into the emulsion.
241 – 3. To form harmless complexes with any aldehyedes carried over from the prehardeners so they cannot react with couplers when the emulsion enters the alkaline first-developer solution.
241 – 4. All color densities are decreased by approximately equal values.
241 – 5. Decreases the contrast.
241 – 6. By changing either the first developer temperature or the processing time.
241 – 7. To drop the pH of the emulsion to a point at which development stops.
241 – 8. Because it chemically exposes the undeveloped silver halides, develops the exposed silver halides to metallic silver, and forms a dye image.
241 – 9. Chemical.
241 – 10. To lower the pH of the emulsion so that the color development reaction stops and to remove the color developing agent from the film.
241 – 11. Magenta.
241 – 12. Silver halides.
241 – 13. To convert all the silver salts to water soluble compounds.
241 – 14. To harden the emulsion, which causes minimum absorption of moisture after drying. It also helps make the dyes more stable.

CHAPTER 2

242 – 1. Splashing or carrying chemicals to the area of the lab where the sensitized materials are (the dry side) could ruin these materials.
242 – 2. To exhaust chemical fumes that could be deterimental to the health and comfort of the personnel working in that area.

243 – 1. Fixer was probably put in the developing tray.
243 – 2. Identify the developing solution by using a tray with a raised X in the bottom and hang a towel in front of the tray.

244 – 1. (1) d.
  (2) b.
  (3) a.
  (4) c.

245 – 1. Arrangement B.
245 – 2. Arrangement A indicates a small wash tray and a prewet bath, which are not needed in print processing. Arrangement C does not have a rinse tray which is needed in print processing.

246 – 1. Not using a water or acid rinse between the developer and fixer.
246 – 2. All variables are correct for graded-contrast paper. The fog is probably due to the printer using variable-contrast paper instead of graded-contrast.
246 – 3. The acid used for the rinse bath is either too strong or the wrong type.

247 – 1. Unplug the printer, dust it, close the condenser door, lower the head, and see that the bellows is not extended.
247 – 2. Double check the lab for classified materials you might have overlooked, then bag, tag, and dispose of the material according to your labs procedures for classified waste disposal.

248 – 1. Fine grain in the product.
248 – 2. Polycontrast roll paper, using a semiautomatic (step and repeat) printer.
248 – 3. Roll type. This lets you process the prints on a continuous processor.

249 – 1. Contrast decreases.
249 – 2. Automatic exposure, automatic-dodging printers.

250 – 1. Closing the platen activates a switch, which turns on the lights to make the exposure.
250 – 2. The platen.
250 – 3. By a sheet of diffusion glass between the light source and the negative.

251 – 1. Overinflation may break the clear glass, which may then settle back onto the working area; underinflation may keep the platen from holding the negative and the printing material in contact (leaving fuzzy corners on the print).
251 – 2. Dusting will cause the material to become airborne, and in time it will resettle onto the working area.
251 – 3. So you'll have even illumination at the exposing plane.

252 – 1. Farther away from.
252 – 2. Longer.

253 – 1. a. Reposition the condenser lens according to the focal length of the projection lens.
b. Level the projection printer head so that the negative plane will be parallel with the easel.
c. Clean the glass plates of the negative carrier.

254 – 1. a. Install the correct lens/condenser combination.
b. Insure that the supply and takeup spindles are identical, and diameter does not exceed 7.6 inches.

255 – 1. a. Diffusion.
b. Condenser.
c. Condenser.
d. Diffusion.
e. Diffusion.
f. Condenser.
255 – 2. Dustless for the 4 x 5 size; glass-sandwich for larger.

256 – 1. To determine the correct exposure and paper contrast.
256 – 2. Their use minimizes the waste of expensive sensitized materials.

257 – 1. First, use a normal paper or normal polycontrast filter. Cut the printing paper into 2-inch strips. Expose the first strip for 2 seconds. For subsequent strips, double the time or add even increments of the initial exposure.
257 – 2. Use a full sheet of normal paper or a full sheet of variable-contrast paper with a normal filter. Give the entire sheet a 2-second exposure. Keep adding 2-second exposures as you cover increasing areas of the paper with an opaque material.

258 – 1. Highlight area.
258 – 2. The comparison of these two areas indicates the contrast of the print.
258 – 3. Usable shadow, middletones, and usable highlight.

259 – 1. a. Increase exposure and run another test to check contrast.
b. Increase contrast.
c. Decrease exposure and increase contrast.
d. Increase exposure and decrease contrast.
e. Change nothing.
f. Decrease exposure and run another test for contrast.
g. Increase exposure and decrease contrast.
h. Decrease contrast.
i. Decrease exposure and contrast.

260 – 1. It produces white borders, which make the prints more appealing to the eye.
260 – 2. To determine the right exposure and paper contrast.
260 – 3. Production of the test print.

261 – 1. Turning off lights and interposing a translucent or opaque medium between the light source and the negative.
261 – 2. Place a translucent medium between the light source and the negative.
261 – 3. Place an opaque medium between the light source and the negative.

262 – 1. It is first placed in a negative carrier. Then the negative carrier is positioned in the projection printer so that the emulsion is down with the negative image backwards (the top of the scene closest to you).
262 – 2. By the easel.
262 – 3. By raising or lowering the printer head.

263 – 1. By either dodging or burning-in.
263 – 2. Keeping the device continually in motion.

264 – 1. Tilt the easel so that the knees are closer to the lens.
264 – 2. Tilt the easel so that the nearby tracks are further from the lens.
264 – 3. Tilt the easel so that the bottom of the building is nearer the lens.
264 – 4. Tilt the easel so that the front of the building is farther from the lens.

265 – 1. (1) To all three.
(2) To 4 x 5 film.
(3) To 5 x 7 film.
(4) To 8 x 10 film.

266 – 1. a. Continuous.
b. None.
c. Intermittent.
d. Continuous.
266 – 2. Insufficient or no agitation.

267 – 1. Uneven development.
267 – 2. Low density and contrast, as well as stains as a result of oxidized developer.
267 – 3. Aerial oxidation and uniform development.

268 – 1. The keeping properties of the final photographic product.
268 – 2. Stop bath, fixing bath, and wash.

269 – 1. Having a pH between four and six and containing a slow-acting acid.
269 – 2. The more exhausted the fixing bath, the more complex the tetrathionates become and the harder they are to wash out.

270 – 1. (1) b.
(2) c.
(3) a.
(4) b.
(5) b.

271 – 1. Temperature and pH.
271 – 2. 4.8.

272 – 1. a. The lines.
b. Areas representing foliage.
c. The lips.
d. The image area.

273 – 1. Evaporation cannot take place.
273 – 2. Diffusion of the water to the surface of the film.
273 – 3. b, c, and e.

274 – 1. The developer would be slower acting.
274 – 2. a. It would increase the pH.
b. It would increase their activity.
c. It would decrease its effect.

275 – 1. The developer components are being used up.
275 – 2. All the restrainer has been used up, so you should add bromide to the solution.

276 – 1. To remove the residual chemicals.
276 – 2. They might fade.
276 – 3. High temperature and high humidity.

277 – 1. The thicker print material holds more solution and decreases the rate that chemicals are diffused from the print.
277 – 2. Agitation insures the continual contact of fresh, uncontaminated wash water with the print.
277 – 3. The rate at which the fresh water diffuses into the print and the chemical-laden water diffuses out of the print.

278 – 1. Mechanical washers, the tray siphon method, and washing in trays.
278 – 2. Six; eight to ten.

279 – 1. It diffuses to the print surface, where it evaporates.
279 – 2. Heated drum dryers, drying cabinets, and air impingement dryers.
279 – 3. The film base contains little or no moisture, while the paper base contains most of the moisture.

280 – 1. The heated dryer method.
280 – 2. Gelatin contraction and/or paper contraction.
280 – 3. Rough handling of the material.

281 – 1. Establish repeatable criteria using a standard viewing table.
281 – 2. View the negative using light reflected from a piece of white paper, bracket the exposure, or use the comparison technique.
281 – 3. Compare the highlight and shadow areas of the negative.
281 – 4. The density range of the negative.

282 – 1. (1) e.
(2) a.
(3) c.
(4) f.
(5) b.

283 – 1. a. Decrease developing time, change to a lower contrast developer, or decrease developer temperature.
b. Increase developing time or solution temperature (both increase negative contrast).
c. Decrease developing time.
d. Have all solutions (including the rinse and wash water) at the same temperature.

284 – 1. Time, temperature, and agitation.
284 – 2. Whenever conditions warrant.

285 – 1. It increases contrast and density.
285 – 2. It decreases contrast and density.
285 – 3. Uneven development increases as agitation decreases, due to the inability of fresh developer to penetrate the emulsion. Decreased agitation decreases the dispersion of development by-products, resulting in retarded development.

286 – 1. a and c.
286 – 2. b.

287 – 1. Increased contrast and density.
287 – 2. None.

288 – 1. Since the replenisher is added in batches, there may be pronounced fluctuations of density and contrast. Also, the buildup in bromide is not compensated for.
288 – 2. It can extend the useful life of developers used for manual film processing.

289 – 1. Detail in both highlight and shadow areas.
289 – 2. The highlight and shadow area, since both areas must contain detail.
289 – 3. Do a retake.

290 – 1. The negative's density range and the printing paper's contrast.
290 – 2. The print density difference that is most pleasing to the viewer when detail is contained in both the highlight and shadow areas.

291 – 1. a. Chemical. These are usually caused by developer on your hands when you handle the paper before processing.
b. Chemical. These can be caused either by the oil excreted by your skin or fixer on your hands when you handle the paper before processing.
c. Chemical. Chemical or light fog, no restrainer, reduced restrainer, or overexposure.
d. Chemical. Lack of agitation in the acid stop bath.

292 – 1. a. Magenta.
b. Cyan.
c. Yellow.

293 – 1. a. Red.
b. Blue.
c. Green.
d. None. Any combination of two additive primary filters over a single light source will absorb 100 percent of the light.
293 – 2. a. Magenta.
b. Cyan.
c. Yellow.
d. White.

294 – 1. Blue and green.
294 – 2. Blue and red.
294 – 3. Red and green.
294 – 4. Green.
294 – 5. Blue.
294 – 6. Red.
294 – 7. None.

295 – 1. The color temperature of the light source, the potential for using corrective filters, the quality of the lens, the accuracy of the timing device, light leakage from the printing equipment, and the ease of operation in total darkness.
295 – 2. Color balance will be off. The product will have too much red dye.
295 – 3. Areas of decreased exposure resulting from foreign matter settling on the filter.

296 – 1. Conversion, light-balancing, color-compensating, and special-purpose filters.
296 – 2. Since color films can't compensate for fluctuations in the color quality of light, you must use filters to modify the light any time it is not absolutely correct.

297 – 1. (1) Color-compensating.
(2) Conversion.
(3) Special-purpose.
(4) Color-compensating.

298 – 1. Even light distribution and low lighting ratios.
298 – 2. 3 to 1.
298 – 3. Measure the lighting with an incident-light meter and be sure to check all areas to be included in the photograph. If necessary, supplement the normal lighting with background lighting and/or side lighting for areas remote from the main and fill-in lights.

299 – 1. It will have thin and washed-out colors.
299 – 2. Overexposure, because it tends to produce a slight overall warming of the print tones. Underexposure tends to destroy the color balance, and you can't correct for both the highlight imbalance and the shadow imbalance.
299 – 3. If there is no visible detail in the shadow areas, the material has been underexposed. If the highlights are blocked up, the material has been overexposed.
299 – 4. Reciprocity failure can lower the effective speed and change the color balance of the emulsion.
299 – 5. Underexposure.
299 – 6. The printer tried to correct for negative underexposure during printing by adjusting the exposure for highlight areas.

300 – 1. The second development reduces the halides exposed in the reversal exposure to black metallic silver and also results in formation of the colored dyes.
300 – 2. The transparency would be completely black. Since there was no first exposure, the second (reversal) exposure would expose all the halides. As all the halides were being reduced to silver, the coupling action would produce a maximum of all dye colors. Maximum dye formation in all colors does not permit transmission of light; hence the transparency is completely black.

301 – 1. The maintaining of correct temperatures and the consistency of agitation.
301 – 2. For repeatability.

302 – 1. Reticulation or frilling.
302 – 2. By immersing the tanks in some type of water bath.
302 – 3. Gaseous-burst agitation.

303 – 1. First development, reexposure, color development, bleach, and fix.
303 – 2. The developer is essentially a conventional black-and-white developer, and it produces a negative silver image.
303 – 3. Cyan dye.
303 – 4. Color development, bleach, and fix.
303 – 5. A negative silver image and a negative color dye image.
303 – 6. a. All emulsion layers.
b. The blue- and red-sensitive emulsion layers.
c. All emulsion layers.

304 – 1. Always try to avoid contact with the chemicals.
304 – 2. Away from possible ignition sources in approved containers that are grounded.
304 – 3. With a rubber bulb or an aspirator pump; never with a mouth-type pipette.
304 – 4. Formaldehyde, ethylene chloride, chloroform, and benzyl alcohol.
304 – 5. Use a vented weighing hood, wear gloves and goggles, and change clothing frequently; also keep the area clean and use clothing without cuffs.
304 – 6. Frequency and extent of contact are the major causes; and color developers, formaldehyde, and potassium dichromate are the most active chemicals.
304 – 7. In tightly stopped bottles. If they're stored for short periods in tanks, the tanks should have floating lids to help prevent oxidation.

305 – 1. The color transparency was produced by the reversal process; therefore, the appearance of a partially clear border would indicate exposure. Since the exposure is local, you can assume that this exposure occurred in the camera as a result of flare or a light leak.
305 – 2. Use one with a Wratten No. 10 filter and a 10-watt lamp, keeping the film at least 4 feet from the safelight.

CHAPTER 3

306 – 1. Back the original with a black piece of paper.
306 – 2. A red filter.
306 – 3. Because high-contrast film has low exposure latitudes.
306 – 4. Use medium contrast film, correct exposure, and correct development.
306 – 5. Use panchromatic film of moderate contrast with the appropriate filter, and watch your exposure and development.

307 – 1. The subject has only one plane, scale of reproduction is involved in many copy situations, etc.
307 – 2. Through-the-lens viewing and focusing, and ability to produce the same size or larger images.
307 – 3. Colored copy subjects.
307 – 4. To prevent distortion of the image.
307 – 5. To make fine image size adjustments.
307 – 6. 45°.
307 – 7. Use an incident meter to compare the light at the center and the corner.
307 – 8. If the surface texture is objectionable, you can reduce it by placing the lights at about 75° to the copy subject.
307 – 9. Open shade.
307 – 10. The copy camera shown in figure 3-1 uses film holders, while the camera shown in figure 3-2 has a vacuum-back film stage and does not require the use of film holders.
307 – 11. Use transmitted light; you remove the opaque copyboard insert and replace it with the black mask insert the opal glass in the back side of the copy board, then position your lights aimed through the mask.

308 – 1. 12 x 15.
308 – 2. 10.
308 – 3. Bellows extension = 13; subject distance = 39.
308 – 4. Bellows extension = 600 mm; subject distance = 300 mm.

309 – 1. The f/stops are a ratio between the lens diameter and the focal length. If you extend the focal length, the f/stops are no longer accurate. Extending the bellows thus affects exposure.
309 – 2. 800 mm.

310 – 1. 1/60 at f/8 (or equivalent).
310 – 2. Focal length.
310 – 3. f/8.

311 – 1. The red objects will be dark and the green and blue objects will be light.
311 – 2. To modify the light striking the film so that the colors of the original are reproduced on prints in essentially the same density as the human eye sees them in their relative shades of gray.
311 – 3. The choice depends mainly on the type of film and the kind of lighting you are using.

312 – 1. 200.
312 – 2. F8.

313 – 1. Use type V, class A film and DK 50 developer.
313 – 2. Class E-1 film and DK-50 developer.

314 – 1. White.
314 – 2. Base.
314 – 3. Red dye or opaque.
314 – 4. Ten percent sodium sulfite.

315 – 1. Blue.
315 – 2. Red.
315 – 3. Deep red.
315 – 4. You may be able to reduce the wrinkles by placing the print under a piece of heavy glass.
315 – 5. Make the best possible copy of it.

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STOP-

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 02 23

PHOTOGRAPHIC FUNDAMENTALS

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (200) The color of light is determined by its

   a. wavelength.
   b. speed.
   c. radiant energy.
   d. absorption or transmission.

2. (201) Photography is made possible because of the ability of a lens to form a sharp image through

   a. diffraction.
   b. dispersion.
   c. reflection.
   d. refraction.

3. (201) The variation of the refractive index in relation to the variation of the wavelength of light is called

   a. chromatic aberration.
   b. diffraction.
   c. dispersion.
   d. refraction.

4. (202) The image formed by a pinhole in a lighttight box is

   a. inverted and faint.
   b. free of diffraction.
   c. made possible by using a prism.
   d. virtual, erect, and free of distortion.

5. (203) The combining of two or more individual lens elements is used to

   a. correct for aberrations.
   b. produce an inverted image.
   c. lessen the effects of optical flare.
   d. produce a brighter image.

6. (204) When a lens is focused on infinity, the distance from the center of the lens to the focal plane is called

   a. focal length.
   b. depth of focus.
   c. depth of field.
   d. object distance.

7. (204) Lens speed is calculated by

   a. adding the focal length of the lens to its diameter.
   b. dividing the diameter of the lens by its focal length.
   c. dividing the focal length of the lens by its diameter.
   d. multiplying the diameter of the lens by its focal length.

8. (205) What is the effective f/stop of a lens with a 1/2-inch diameter and a focal length of 8 inches?

   a. f/4.
   b. f/8.
   c. f/16.
   d. f/32.

9. (206) The quality of photographic definition is dependent upon resolving power,

   a. image size, contrast, and graininess.
   b. sharpness, tone reproduction, and graininess.
   c. graininess, tone reproduction, and image size.
   d. tone reproduction, image size, and sharpness.

10. (207) The inability of a lens to bring different wavelengths of white light to focus on the same plane is called

    a. coma.
    b. astigmatism.
    c. spherical aberration.
    d. chromatic aberration.

11. (208) Optical flare can be decreased in a lens by

a. increasing the number of lens elements.
b. decreasing the maximum aperture of the lens.
c. separating the lens elements.
d. coating the lens.

12. (209) What are the three basic components on an aerial camera?

a. Body film assembly, lens cone, and body drive mechanism.
b. Lens cone, film magazine, and body drive assembly.
c. Film magazine, lens cone, and body film assembly.
d. Body drive assembly, film magazine, and altimeter.

13. (210) Which camera was developed for *low* altitude, *high* speed missions?

a. Panoramic camera.
b. Special format camera.
c. Continuous strip camera.
d. Framing camera.

14. (211) What type of photograph is taken with the camera axis perpendicular to the earth's surface?

a. Oblique.
b. Vertical.
c. Split vertical.
d. Tri-metrogon.

15. (212) Side Looking Airborne Radar (SLAR) is

a. a useful all-weather, day or night mapping and reconnaissance sensor.
b. an optical imagery system.
c. a day or night, all weather, optical system.
d. an optical system used in mapping and reconnaissance photography.

16. (213) The final inherent characteristics of an emulsion are determined to a great extent by the

a. type of equipment in which it is exposed.
b. type of base material used to support the emulsion.
c. ingredients and the manner in which they are put into the gelatin.
d. overcoating and substratum coating layers of the sensitized material.

17. (214) One of the chemical properties of a satisfactory film base is that it

a. must not resist chemical action.
b. must be resistant to moisture.
c. must not be inert to chemicals contained in the emulsion.
d. should repel the emulsion in given situations.

18. (215) The film layer which causes the emulsion to adhere to the base material is the

a. overcoating.
b. anticurl coating.
c. antihalation coating.
d. substratum coating.

19. (216) If you are using orthochromatic film to make a portrait of a female officer, how will her red lipstick appear on the print?

a. White.
b. Natural.
c. Light gray.
d. Very dark.

20. (216) A true-tone rendition is best achieved by selecting films having a sensitivity classification of

a. panchromatic.
b. orthochromatic.
c. monochromatic.
d. blue-sensitive.

21. (217) The sensitivity of film to light can best be defined as

a. desired density.
b. film speed.
c. latitude.
d. inherent contrast.

22. (218) A high-speed emulsion usually has a

a. high contrast.
b. coarse grain.
c. greater overall density.
d. high resolving power.

23. (219) Inherent contrast can be *best* described as the ability of an emulsion to

a. record fine detail.
b. respond to low levels of illumination.
c. produce contrast.
d. produce a large range of brightness values.

24. (220) The extent to which the exposure of a negative can deviate from the normal and still produce an acceptable image is known as

a. exposure index.
b. emulsion speed.
c. exposure latitude.
d. resolving power.

25. (221) Even though film latitude provides a safety factor, it is better to use the lesser exposures since heavier densities

a. lengthen the printing time.
b. cause possible changes of contrast.
c. often contribute to other deficiencies.
d. all of the above.

26. (222) The ability of an emulsion to reproduce fine detail results from its

a. film latitude.
b. resolving power.
c. fine grain.
d. restitution capability.

27. (223) Static electricity markings are most common in negatives produced on film that was stored under conditions of

a. low temperature.
b. high temperature.
c. high humidity.
d. proper refrigeration.

28. (224) Most film for domestic use is packaged by the manufacturer at a relative humidity of

a. 40 percent.
b. 45 percent.
c. 50 percent.
d. 55 percent.

29. (225) The emulsion layers of printing papers must be thinner than the emulsion layer on film because

a. processing time must be kept to a minimum.
b. a thick emulsion would have too much contrast.
c. light must travel through the emulsion layer twice.
d. the image would be diffused if a thick emulsion were used.

30. (226) To make a print in the least possible time, which of the following papers should you use?

a. Double weight.
b. Light weight.
c. Single weight.
d. Middle weight.

31. (227) The inherent contrast in variable-contrast emulsions is dependent upon the

- a. duration of the light used for exposing.
- b. intensity of the light used for exposing.
- c. color of the light used for exposing.
- d. dilution of the developer used for processing.

32. (228) Which of the following Wratten Series safelight filters should you use when exposing and processing variable-contrast emulsions?

- a. OA.
- b. OC.
- c. OD.
- d. AO.

33. (229) Inadequate protection of photographic paper while in storage can result in all the following *except*

- a. increased fog.
- b. inferior tone reproduction.
- c. decreased emulsion sensitivity.
- d. increased contrast.

34. (230) Moistureproof containers are normally used for sensitized materials destined for

- a. export.
- b. immediate use.
- c. domestic use.
- d. refrigeration.

35. (231) The sensitivity of the three layers of emulsion for reversal color film from the top emulsion layer to that next to the base is

- a. red, green, and blue.
- b. blue, green, and red.
- c. yellow, cyan, and magenta.
- d. magenta, cyan, and yellow.

36. (231) The blue exposure affects only the top emulsion layer of a subtractive color film because

- a. there is a yellow filter below the top emulsion.
- b. there is a anti-blue filter incorporated within the other layers.
- c. the blue recorded in the other emulsions is removed during processing.
- d. the layer emulsions are not blue sensitive.

37. (232) The spectral energy distribution of a light source can be measured by using

- a. a photoelectric exposure meter.
- b. a photometer with colorhead attachments.
- c. a three-point color temperature meter.
- d. sensitometric procedures.

38. (232) The Kelvin rating of a light source expresses the measure of a temperature that is equivalent to that of

- a. an object heated to approximately 2900 degrees F.
- b. centigrade temperature plus 273 degrees F.
- c. a color light source on a fixed voltage.
- d. a black body heated until its heat is equal to that of the source of radiation.

39. (233) In the processing of exposed color reversal film, the function of the first developer is to

a. convert latent images to subtractive primary images.
b. change negative images to positive images.
c. produce negative silver images.
d. produce positive silver images.

40. (234) A processed reversal color film appears very light in color; this is a probable result of

a. underexposure.
b. overexposure.
c. low process temperature.
d. excessive bleach time.

41. (235) The property of color that relates to the purity or saturation of a color is

a. hue.
b. value.
c. achromaticity.
d. chroma.

42. (236) During storage, changes in color dyes in color prints can result if the

a. stabilizer processing step was not used.
b. relative humidity of the storage area is 45 percent.
c. prints are stored face to face.
d. prints are protected from normal room light.

43. (237) To decrease the possibility of fading, the maximum milligrams per square inch of hypo allowable in color emulsion is

a. 0.002.
b. 0.003.
c. 0.004.
d. 0.005.

44. (238) Which of the following developing agents possesses the lowest reducing potential?

a. Metol.
b. Pictol.
c. Hydroquinone.
d. Rhodol.

45. (239) Boric acid is sometimes added to a fixing bath to

a. harden the emulsion.
b. retard the formation of sludge.
c. neutralize the action of the developer.
d. prevent the decomposition of the fixer.

46. (240) In the EA-5 process, which solutions have both working and replenisher formulas?

a. First developer and bleach.
b. Color developer and bleach.
c. First developer and color developer.
d. Stabilizer and neutralizer.

47. (241) Making the color emulsion more resistant to physical damage during processing is the function of the

a. prehardener.
b. stabilizer.
c. fixer.
d. first stop bath.

48. (242) What should the laboratory temperature and relative humidity be to provide a comfortable environment for the worker?

a. 60°F and 30 percent.
b. 65°F and 40 percent.
c. 70°F and 50 percent.
d. 75°F and 60 percent.

49. (243) In the arrangement of equipment for processing film in total darkness, which one of the following unwritten laboratory rules would *not* apply?

a. Place timer in a spot where you can reach it.
b. Know where the trays are located.
c. Know which tray is which.
d. Know where the safelights are located.

50. (244) When processing film, the rinse bath between the developer and fixing bath is normally used to

a. harden the emulsion.
b. prolong the life of the developer.
c. dissolve the unexposed silver halides.
d. dilute the developer and prevent pinholes.

51. (245) Oversized trays are recommended for print processing primarily because

a. more prints can be processed at one time.
b. solution carry-out is greater than with film.
c. larger quantities of solutions deteriorate faster.
d. larger quantities of solutions maintain a more consistent temperature.

52. (246) Which of the following processing solution temperatures would best insure proper print development?

a. 62°F.
b. 68°F.
c. 72°F.
d. 78°F.

53. (247) After a condenser type projection printer has been unplugged and dusted, what is left to do?

a. Lower the printer head, extend the bellows, close the condenser door, and position the dust cover.
b. Lower the bellows and printer head, close the condenser door, and cover the printer.
c. Lower the bellows, raise the printer head, close the condenser door, and cover the printer.
d. Extend the bellows, raise the printer head, close the condenser door, and cover the printer with a plastic cover.

54. (248) How long would it take to develop 3,000 feet of sensitized material if it requires 4 minutes of development, and the developer tank has a capacity of 40 feet?

a. 4 hours.
b. 5 hours.
c. 6 hours.
d. 7 hours.

55. (249) When printing a roll of reconnaissance film containing extreme variations in exposure and contrast, for best results in the shortest time you should print this film on

a. a manually operated contact printer using graded paper.
b. a manually operated contact printer using variable-contrast paper.
c. an automatic-exposure, automatic-dodging printer.
d. a two-stage rectifying printer.

56. (250) Use the clear acetate section of the filter roll in an EN-22A contact printer when

a. printing on graded contrast paper.
b. printing on variable contrast paper.
c. the negative is excessively dense.
d. you do not need borders on prints.

57. (251) All of the following should be considered as required manual contact printer preoperational tasks *except*

a. cleaning the printer and printing area.
b. checking the platen for correct inflation.
c. insuring the use of a timer.
d. checking the safelight illumination.

58. (252) What is the main advantage of projection printing over contact printing?

a. Projection prints require less exposure time.
b. Large images are easier to focus and spot.
c. A large choice of paper surfaces is available.
d. The size of the prints is not restricted to the size of the negative.

59. (253) A projected image that decreases in brightness outward from the center of the image is the result of

a. improper focusing.
b. insufficient enlargement.
c. improperly positioned condenser lens.
d. the negative being upside down.

60. (254) Before using the horizontal-projection printer for production work, a proper procedure to follow is to make sure

a. the takeup spindle is 9 inches in diameter.
b. the takeup spindle is larger than the supply spindle.
c. no magnification/focus window on the easel drive assembly has lighted.
d. the condenser lens and lamp assembly match the objective lens assembly.

61. (255) If you make a 3 1/2-diameter enlargement from a negative area measuring 1 1/2 inches by 2 inches, the resulting print image will be

a. 3 1/2 by 5 inches.
b. 5 1/4 by 7 inches.
c. 7 1/2 by 9 inches.
d. 8 by 10 inches.

62. (256) Printing test strips are most useful when

a. the quality of the negatives is in doubt.
b. a large number of prints must be produced.
c. the negative contains a wide range of tones.
d. you cannot judge the density and contrast of the negative.

63. (257) The first series of contact printing test strips should be

a. made on contrast number 2 paper.
b. processed at varying development times.
c. developed using high, medium, and low-contrast formulas.
d. exposed in a range going from underexposed to a normal exposure.

64. (258) The areas of the negative that should be included in the test strips are the

a. sky and image point of interest.
b. sky, highlights, and middle tones.
c. highlights, shadows, and middle tones.
d. middle tones and image point of interest.

65. (259) After determining the correct exposure by viewing test strips, you select the proper contrast by viewing the

a. highlight area of the test strip.
b. shadow area of the test strip.
c. middle tones of the test strip.
d. test strip through various filters.

66. (260) In contact printing, which of the following would be true of masking?

a. The mask must be rectangular.
b. Masking is done with an easel.
c. The mask is placed between the negative and the paper.
d. The mask is placed between the negative and the light source.

67. (261) What photographic term is used for the process of varying the exposure in specific areas of a print?

a. Dodging.
b. Painting.
c. Refraction.
d. Projection.

68. (262) One reason for stopping down the lens prior to projection printing is to

a. diffuse the image.
b. shorten the printing time.
c. increase the depth of field.
d. insure the proper image size.

69. (263) Dodging and burning-in devices must remain in motion during exposure to prevent

a. distortion of the printed image.
b. air bells from forming on the print.
c. uneven development of the printed image.
d. a sharp outline of the device on the print.

70. (264) Exaggerated perspective can be corrected through the use of a projection printer by

a. using a lens that is corrected for curvilinear distortion.
b. sliding the easel either horizontally or vertically as appropriate.
c. altering the relationship of the negative plane and the easel plane.
d. repositioning the negative in the carrier so that the image area being enlarged is centered.

71. (265) Which one of the following film processing tanks would most likely be designed for processing in normal room light?

a. 4 X 5 inch.
b. 5 X 7 inch.
c. 8 X 10 inch.
d. 11 X 14 inch.

72. (266) When sensitized material is developed without agitation, image development

a. is increased.
b. is continuous.
c. becomes very vigorous.
d. slows down.

73. (267) Spray jets are used with a circulation system for agitation

a. because they cost less to operate.
b. since they reduce the risk of contamination.
c. to provide a more vigorous method of agitation.
d. because they can cover a wider area of sensitized material.

74. (267) The waves that are sometimes produced by mechanical agitation devices are known as

a. sine waves.
b. running waves.
c. standing waves.
d. processing waves.

75. (268) All of the following factors contribute to the keeping properties of photographic products *except* the

a. wash.
b. stop bath.
c. fixing bath.
d. developer.

76. (269) In order to obtain the best archival quality print, you should use a stop bath solution compound from a

a. weak acid and maintain the solution at a pH of 2 to 4.
b. strong acid and maintain the solution at a pH of 2 to 4.
c. weak acid and maintain the solution at a pH of 4 to 6.
d. strong acid and maintain the solution at a pH of 4 to 6.

77. (270) As washing time increases, the amount of hypo diffusing out of the emulsion

a. increases.
b. decreases.
c. remains the same.
d. fluctuates.

78. (271) The amount of water that gelatin can absorb is largely determined by the

a. physical state of the gelatin.
b. temperature and pH of the water.
c. length of time the gelatin is submerged in the water.
d. relative humidity of the air surrounding the negative.

79. (272) A normally exposed and developed negative dries

a. uniformly.
b. in a nonuniform manner.
c. without the presence of air.
d. more rapidly than a dense negative.

80. (273) One of the main problems in drying negatives is the

a. formation of water spots on the surface of the film.
b. curling of the film toward the emulsion and a tendency to be brittle.
c. movement of warm dry air away from the negatives after it has picked up moisture.
d. necessity of controlling the rate of drying by adjusting the air velocity.

81. (274) The main difference between developer formulas is the

a. kind of chemicals used in each formula.
b. required dilution of the stock solutions.
c. concentration of each chemical in the formula.
d. quantity of accelerator required for each formula.

82. (275) Which one of the following printing scenes will have the most effect toward exhausting a developer solution?

a. Sun setting on the horizon.
b. Aerial photo of forest area.
c. Black-and-white line drawings.
d. Tree in the backyard on a cloudy day.

83. (276) Prints are washed after fixation to prevent all the following *except*

a. yellowing on the print.
b. bleaching of the highlights.
c. an increase in print contrast.
d. staining of the unexposed areas of the print.

84. (277) The normal washing time for double-weight prints is

a. 30 minutes.
b. 45 minutes.
c. 60 minutes.
d. 90 minutes.

85. (278) When tray washing single weight prints, the water should be changed

a. 5 times at 4 minute intervals.
b. 6 times at 5 minute intervals.
c. 7 times at 6 minute intervals.
d. 8 times at 7 minute intervals.

86. (279) Which one of the print drying methods is the most common for handling sheet paper?

a. Suspending prints in a drying cabinet.
b. Hanging prints from a clip in a lab.
c. Running prints through a heated drum type dryer.
d. Placing prints on a bobbinet cloth material.

87. (280) When finishing prints, the defect known as plumming is a result of

a. drying the print at an erratic rate.
b. too much hardening of the emulsion.
c. the application of heat in the drying process.
d. a shrinkage differential between the emulsion and the backing.

88. (281) You can determine the quality of a negative visually by viewing it with light

a. emitted from an OA safelight.
b. reflected from a piece of white paper.
c. reflected from the gray side of aneaural-test card.
d. of the same intensity as used to expose the film.

89. (282) Reticulation can be caused by

a. too strong an acid in the developer.
b. too strong a concentration of hardener in the fixing bath.
c. too great a difference in the temperature of the various solutions used.
d. an insufficient water rinse between the developing solution and the hypo.

90. (283) A possible cause for excessive negative density could be any of the following *except*

a. a "dragging" shutter.
b. a high scene reflectance.
c. an improperly operating exposure meter.
d. an improperly calculated developing time and temperature combination.

91. (284) The three variables that are of greatest concern when processing film manually are

a. material washing time, agitation, and developing time.
b. agitation, developing time, and developer temperature.
c. developer temperature, material washing time, and agitation.
d. developing time, developer temperature, and material washing time.

92. (285) If the developer temperature is raised above normal for processing,

a. agitation should be increased.
b. wash temperature should be decreased.
c. development time should be decreased.
d. development time should be increased.

93. (286) When must a fixing bath be replaced?

a. When the pH decreases.
b. When the film clears in less than 2 minutes.
c. When it no longer stops the action of the developer.
d. When silver halides are turned to water-soluble compounds.

94. (287) Steadily increasing negative contrast from one batch of negatives to the next can most likely be attributed to

a. the use of different type films.
b. changes in scene brightness range.
c. over replenishment of the developer.
d. a decrease in the developer restrainer.

95. (288) Which of the following replenishment methods is most often used for tray development?

a. Bleed method.
b. Topping-up method.
c. Intermittent method.
d. Recirculation method.

96. (289) When determining the ideal print density for any negative,

a. hold the test print at arm's length.
b. view the test print under safelight illumination.
c. compare the test strip highlight and shadow areas.
d. make a test strip even though the negative may appear easy to print.

97. (290) Print contrast is based on the contrast of the printing paper and the

a. density range of the negative.
b. scene brightness range of the subject.
c. time of day the exposure was taken.
d. location of the subject.

98. (291) Purple discoloration of a print is caused by

a. exhausted developer solution.
b. lack of agitation in the acid stop bath.
c. an excess of potassium bromide in the developer.
d. the failure to agitate prints properly in the fixing bath.

99. (292) What colors of light are used in the additive color process?

a. Red, yellow, and blue.
b. Red, green, and blue.
c. Yellow, magenta, and cyan.
d. Magenta, green, and blue.

100. (293) What color light will be produced when light is transmitted by a green and red filter superimposed on a screen?

a. Yellow.
b. Magenta.
c. Cyan.
d. White.

101. (294) A subtractive primary filter

a. represents white light minus 1 additive primary color.
b. represents white light minus 2 additive primary colors.
c. transmits approximately 1/3 of the white light.
d. transmits its complimentary color.

102. (294) If you use the subtractive color process to obtain an original primary color of the additive process, which two subtractive primary filters could be used to obtain green?

a. Red and magenta.
b. Magenta and yellow.
c. Yellow and cyan.
d. Cyan and red.

103. (295) When making color prints, your filter pack should always include

a. an N-61 filter.
b. a Wratten No. 10 filter.
c. a 50R filter.
d. a CP2B filter.

104. (296) All of the following may be used to compensate for fluctuation in color quality of light *except*

a. conversion filters.
b. light balancing filters.
c. color compensating filters.
d. color contrast filters.

105. (297) If you want to absorb ultraviolet energy and a small amount of blue and green without degrading the overall color of the transparency, you should use

a. more exposure.
b. a skylight filter.
c. a light yellow filter.
d. a color compensating filter.

106. (298) To read the fill-in illumination on the incident-light meter, you should turn off the

a. background light.
b. hair light.
c. key light.
d. side light.

107. (299) When using Vericolor Type L film for a very long exposure time, you must compensate for reciprocity effects on latitude and

a. exposure range.
b. color balance.
c. scene brightness range.
d. contrast.

108. (300) In the reversal color film development, the dyes are formed

a. just after the bleaching step.
b. in conjunction with the bleaching step.
c. prior to the reversal exposure.
d. during the second development.

109. (301) The two factors which have the greatest effect upon color processing are

a. quality of safelight and thermometer accuracy.
b. agitation control and temperature control.
c. agitation control and purity of the fresh water.
d. temperature control and age of processing chemicals.

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110. (302) During the processing of color materials, frilling of the edge of the emulsion is a very good indication that the

a. processing time is not correct.
b. solution temperature is out of control.
c. gaseous-burst agitation system is not operating properly.
d. emulsion was not coated properly.

111. (303) How many steps are in reversal color processing?

a. Three.
b. Four.
c. Five.
d. six.

112. (304) Partially used color processing solutions

a. must be thrown away immediately.
b. should be discarded within one week.
c. should not be saved for more than 48 hours.
d. can be stored indefinitely in stoppered bottles.

113. (305) A transparency that shows clear streaks or areas of washed-out color indicates

a. failure to use a lens that was color corrected.
b. fogging during development.
c. underexposure of the washed-out areas.
d. accidental use of a color filter during exposure.

114. (306) What color filter will produce maximum contrast when copying a blueprint?

a. Yellow.
b. Red.
c. Blue.
d. Green.

115. (307) When copying matte or rough textured subjects, move your lights until they are nearly parallel to the copy surface and at an angle of approximately

a. 25 degrees.
b. 43 degrees.
c. 45 degrees.
d. 75 degrees.

116. (308) The lens-to-subject distance for a 1:1 scale when using a bellows extension of 12 inches should be

a. 12 inches.
b. 18 inches.
c. 24 inches.
d. 36 inches.

117. (308) If a mosaic with a scale of 1:10,000 was to be copied to a scale of 1:8000, a distance of 5 inches on the mosaic would be equal to how many inches on the copy?

a. 5 1/4 inches.
b. 6 1/4 inches.
c. 7 1/4 inches.
d. 8 1/4 inches.

118. (309) The f/stops on a lens are a ratio between the

a. lens speed and subject distance.
b. lens diameter and shutter speed.
c. lens speed and focal length.
d. focal length and the diameter of the aperture.

119. (310) After setting up your subject and getting the image composed to the size and lighting arranged, your final step is to

a. take a meter reading.
b. adjust the focal length.
c. set the lens speed.
d. load the film.

120. (311) A complete set of filters for copying should include

a. three contrast filters and five correction filters.
b. three contrast filters and three correction filters.
c. five contrast filters and five correction filters.
d. three correction filters and five contrast filters.

121. (312) A basic exposure without a filter is 1/400 at f/16; after installing a filter with a factor of 4 the new exposure would be

a. 1/100 second at f/16.
b. 1/100 second at f/4.
c. 1/200 second at f/16.
d. 1/200 second at f/4.

122. (313) Which of the following film/developer combinations should be used to copy a continuous tone color print on black-and white film?

a. Class E; D-19.
b. Class E; D-50.
c. Class A; D-19.
d. Class A; DK-50.

123. (314) When blocking a negative with 1A red dye, apply it with a

a. brush.
b. mapping pen.
c. cotton swab.
d. wooden applicator.

124. (315) What color filter can be used to improve the contrast in the reproduction of an old yellowed photograph?

a. Red.
b. Blue.
c. Yellow.
d. Green.

END OF EXERCISE

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CDC 23350

IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

Volume 3

Continuous Imagery Production

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Preface

THIS THIRD volume of CDC 23350, *Imagery Production Specialist*, is intended to increase your knowledge of the skills needed to qualify you for the duties of an Air Force imagery production specialist. The material contained herein is a continuation of, and an expansion on, the available formal school training and the first two volumes you have already completed. Read the text carefully, work the exercises, and apply the knowledge you acquire to your on-the-job training.

In Chapter 1 we discuss preprocessing considerations. This includes film preinspection and the procedures and equipment used for correcting material defects.

Chapter 2 covers processor preparation and certification. This includes those tasks to be performed during processor startup, the controls that should be established, use and certification of processor equipment, and certification procedures.

In Chapter 3 you will study the requirements for processing several types of photographic products, threading leadered-type processors, material splicing during operation, and monitoring the process. There are also objectives on emergency procedures for film breaks.

Chapter 4 involves postprocessing tasks. In this chapter you will find information on processor shutdown, troubleshooting, special cleaning methods, and corrosion control.

Chapter 5 discusses reproduction systems that are different from those using either a color dye image or a black metallic silver image. Because of the silver shortage, these might be called systems of the future.

In Chapter 6 we discuss material editing and assembling. This includes original roll breakdown, attaching and annotating leader material, and rollfilm assembly for printing.

Chapter 7 covers preprinting requirements: titling and cleaning. This information covers the certification, startup, operation, shutdown, and preventive maintenance of selected titlers and cleaners used in the Air Force.

Chapter 8 continues with the study of continuous rollfilm printing, including preventive maintenance procedures.

Chapter 9 is the final chapter of this volume, and here we discuss many of the tasks associated with motion picture production. This chapter contains information on cuing special effects, programming printer tapes, notching and cuing, and printing wet gates.

This volume is valued at 54 hours (18 points).

Material in this volume is technically accurate, adequate, and current as of May 1985.

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CHAPTER 1

Preprocessing Considerations

AN IMAGERY production laboratory is responsible for the production of extremely valuable material. There is no room for error. Precision work starts with a specified process and specified materials; the process is evaluated, and any faulty or out-of-tolerance operation is corrected. Processing includes many variables. Highly specialized automated processing units are used to control these variables. Even though the machines are automated, you must still adjust them for proper operation.

In order to produce a desired result, you must also be familiar with equipment other than the processing machine and its associated processing techniques. Therefore, let's begin by considering the preliminary steps before rollfilm is actually fed into the processing machine.

1-1. Preinspection of Unprocessed Film

As an imagery production specialist, the first preliminary step is, of course, the receipt of the film to be processed. The film might be a single roll or a number of rolls; it might be negative material, or it might be positive material. If the film is original material, we realize that it might be impossible to reshoot the mission if we damage the film. After the film is in our hands, we begin the important preinspection procedures discussed in this section.

400. State the procedures for preinspecting film.

Purpose of Preinspection. To preclude the loss of unprocessed rollfilm during processing, it must be preinspected for physical defects which could result in its loss. Even though some of the camera-system-produced defects will not result in material loss, this preinspection is a critical step. To further complicate this task, most original camera films are either panchromatic or infrared emulsions. Because of this, the inspection must be performed in total darkness. Also, because of the importance placed on the original record, and the possibility of further damage which might be incurred from environmental contaminations, this material must be preinspected in an environmentally controlled area.

The purpose of preinspection is twofold. First, the film is checked for physical damage such as tears, nicks, and crimped edges. Some of these defects are repaired while others are eliminated from the original roll. Second, during the preinspection phase, short rolls of original camera material are assembled into long lengths for processing convenience. This last task is accomplished only when certain type processors are available for original negative (ON) processing.

Exercises (400):

1. What is done during the preinspection of unprocessed film?

401. Briefly explain what is done during the removal of major physical defects before processing original camera film, and why it is done.

Preinspection Functions. To do this type of inspection, you need a preinspection and splicing table such as the one shown in figure 1-1. Using this table in the dark or with an appropriate safe light, you inspect the film as it is transferred from the supply spool to the motor-driven takeup spool. Carefully examine the film for tears or nicks by lightly feeling the edges. White clean-room gloves and other clean-room clothing must be worn during this procedure. Gloves are used to protect the film from fingerprints. Furthermore, when the gloves are of the lint-free cotton or nylon material, film tears will usually snag the cloth material as it is transported from the supply to takeup reel. This action aids the operator in locating many of the physical defects.

Small nicks or tears are repaired by stopping film travel and covering the defect with transparent "Mylar" tape. Any tear that extends more than 1 inch into the film is considered a major defect and requires special consideration. If you find such a defect, remove the defective section of the roll and splice the free ends of the original film together. If an attempt is made to repair a tear of this magnitude, the transparent tape will cover portions of the exposed frame and will result in loss of possible highly critical intelligence information. The section removed is saved and processed by hand to preserve what could be important subject matter.

Be sure that you wind the film slowly. If the transport is too fast, you may miss a defect. Fast winding can also cause static electricity to build up. Because static electricity may discharge and fog the film, you must wind at a moderate and even rate. Fast winding can also cause the film to bind on the spools and produce photographic or mechanical damage, such as pressure streaks, cinch marks, and scratches.

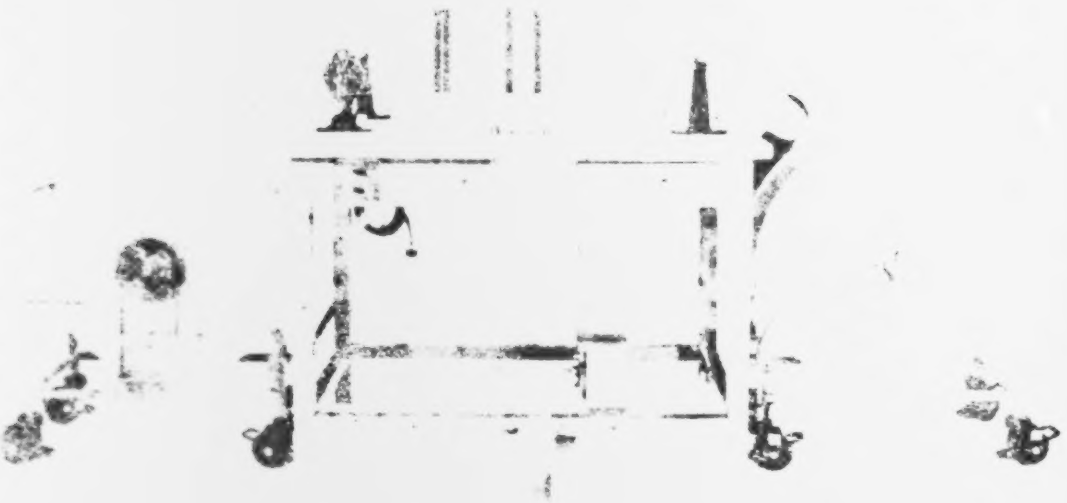

Figure 1-1. Film preinspection and splicing table.

Exercises (401):

1. Give two reasons why clean-room gloves should be worn during preinspection.

2. Why should tears that extend more than 1 inch into the film be removed?

402. Given illustrations depicting physical defects, determine which physical defects are major and should be removed if local operating instructions permit.

Defect Identification. If not corrected, physical defects, such as torn or crimped edges in exposed original material taken directly from a camera magazine, can cause mistracking, tearing of the film, or jamming of a processing machine. While it is impossible to include samples of physical defects in this CDC, their presence in unprocessed materials is important enough that you must be constantly aware of them and know what to do if you are responsible for preinspection functions.

In figure 1-2, some defects that you may find present in film inspection are shown. While we cannot depict what these defects will feel like to you, you can sense this feeling and learn to recognize it as either a major or minor defect. Refer to the text in Objective 401 for the difference between major and minor defects.

Exercises (402):

1. Using figure 1-2, determine which defects would be classified as major.

1-2. Splicing Operations

Just as important as locating the physical defects are the procedures used to correct them. After the major defect has been located and removed from the roll, the two ends of the film must be spliced back together. If the splice is not made correctly, you have not solved the problem of physical defects.

403. Given a list of problems that might arise because of improper slicing techniques, determine the cause of particular problems.

Splicing. The operations of cutting and splicing are used extensively with aerial rollfilm processing. Splicing is a relatively simple operation, but an important one. The splice must be durable in both the wet and dry state and must be capable of withstanding movement through various machines. Additionally, the splice must not have a thickness appreciably greater than the original film thickness. A thick splice is especially undesirable when assembling undeveloped film lengths on a single roll, since pressure marks may form on subsequent laps of the roll. Also, a thick splice may cause equipment to jam.

Another requirement of a splicer (and your use of it) is that edge continuity and angular relationship must be maintained exactly from one roll to another. This continuity is necessary to obtain proper tracking during passage of film through the processing machine or other device. If film does not track properly, it may wrinkle or the edge may be torn, as it tends to climb spool flanges or the sides of rollers. Minor deviations in the relationship between rolls are taken care of since the machine transport rollers are a bit wider than the film, but there is a limit to the effectiveness of the increased width.

Tape-heat splicers. A typical example of a splicer which uses the tape-heat method is the one previously illustrated

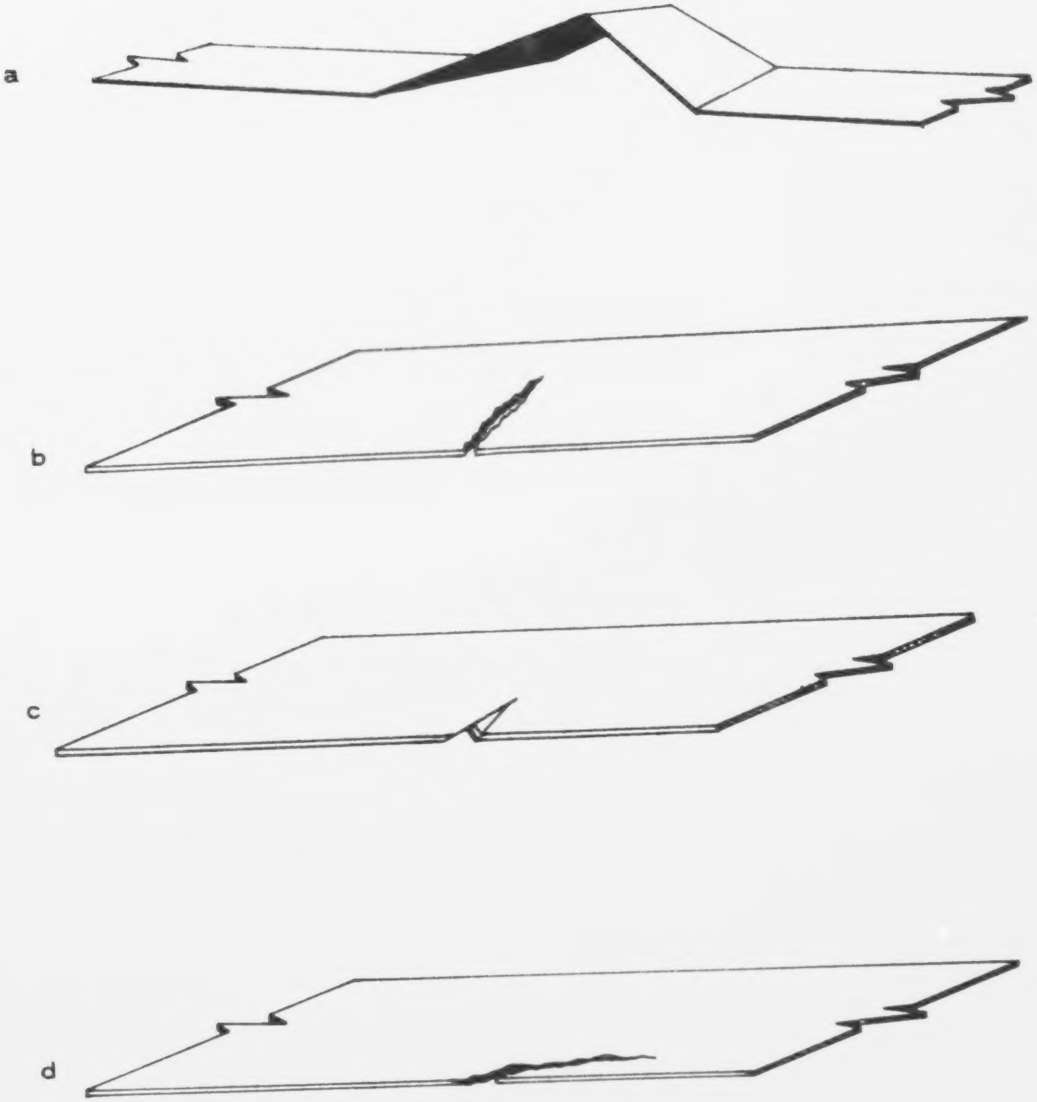

Figure 1–2. Physical film defects.

in figure 1-1. The correct temperature is important to the making of a good splice. Splices made with the temperature below the recommended level may hold temporarily, but are apt to separate during processing. If the temperature is too high, the film may blister or wrinkle near the splice. Therefore, check the temperature with a suitable pyrometer before the splicer is used. Also, keep the face of the heating platen clean at all times.

The splicer assembly is installed on the tabletop between the supply and takeup rewinds. The splicer consists of a baseplate with a channel about 9½ inches wide to aid in aligning film while splicing, a pair of locking clamps to hold the film ends in place, a cutter, and a heating bar which is lowered and locked in place to provide heat and pressure. All splices are made with heat splicing tape. You must align both supply and takeup spindles so that the back edge of the film lies parallel to and touches the rear guide of the film channel of the baseplate. Adjust the spindles by releasing the knob on the base of either the front or the rear bracket and sliding either or both brackets to the correct position.

Splicing devices similar to the one described above are also incorporated on most processing machines. Thus, continuous operation can be maintained even though supply magazines must be changed from time to time. It is advisable to practice the magazine changing and splicing procedure until you are proficient. When the machine is in operation, the splice must be made before the film in the load accumulator (dry tank) is exhausted. Speed in this operation must not lead to the making of an unsatisfactory splice.

Ultrasonic splicer. This splicer is used in splicing rollfilm without employing tape or adhesives. It fuses (welds) two pieces of film together by means of ultra-high frequency sonic waves which create the required heat for fusion.

The unit requires about 15 square feet of floorspace and should be located close to a power source of 115 volts AC. During operation it uses about 10 amperes of current. Film capacity of this unit is 500 feet of rollfilm in a maximum width of 9½ inches.

The major advantages of this type of splicing are high splicing speed, no requirement for tape or adhesives, and the system lending itself to clean-room operation since the only material required is the film itself.

Exercises (403):

1. A splice that had been made on a heat-type splicer separates during processing. What was the probable cause?

2. A roll of film containing a "Mylar" tape splice jams at the squeegee during processing. What probably caused this jamming?

3. Film containing a splice made with the ultrasonic splicer begins mistracking. What could cause this mistracking?

CHAPTER 2

Processor-Preparation and Certification

IN ANY BASIC processing system, you must consider the processing time, the temperature, and the rate of agitation. In addition to these variables, you must control the recirculation of the solutions, filtration, replenishment, carryover of solutions from the one tank to another, film drying, etc. As you will see, each processing variable is controlled as a separate entity. But, you must remember that all these factors are interdependent. For example, you determine that a specific feet-per-minute rate is desirable. This rate, other factors remaining constant, is correct for only one particular developer temperature. If the temperature goes up, the developer is more active and temperature must be reduced or the feet-per-minute rate must be increased. Note that we considered only two variables and you balanced one against the other. A third variable, such as replenishment, must be balanced against the other two variables which are now considered as standards, and so on through the list of variables. What you do to any one influences the others. All this must be balanced against variables that are not a part of processing, such as changes in film type, haze encountered during the mission, ground-scene characteristics, etc. With all of this in mind, let's look at some of the major processing considerations.

2-1. Startup Procedures

There are two factors that affect the proper operation of an imagery processor: housekeeping procedures and work habits. The housekeeping procedures were covered in earlier readings. The work habits are developed through experience and derived from a checklist. The procedures which follow may vary from one unit to another, however, there are some basic procedures which must be followed for successful processor operation.

404. State what would happen if certain procedures were performed improperly during machine startup.

Machine Startup. As with any electrical device, component switches should be in the OFF position before any power is applied. This is especially true of a Versamat processor. Also the speed control knob on the control must be set at 0 feet-per-minute, or maximum counterclockwise. If, for instance, the main power was turned on with the main drive switch in the ON position and the speed control set at a speed other than zero, serious damage to the nylon gears and drive would result. Before power is applied to the Versamat, the water must be turned on and adjusted to a flow rate of 0.5 gallons per minute at a temperature 5° less than the intended developer temperature. The water in a Versamat is actually used three times. It enters the machine and flows through the heat exchanger, where the developer is cooled if necessary. From there it flows through the spray wash rack in the last wash tank. When this tank is approximately one-half full, the water overflows into a standpipe and is pumped into the first wash tank, where the film is washed by immersion. This water pump is controlled by the main drive switch. If this switch is turned on before the last wash is at least one-half filled, the pump will run dry and may burn out. As a general rule, never apply power to any portion of a Versamat processor unless the water is running and the last wash tank is at least 1/2 full.

Although the dryer fan and dryer heaters are interconnected (the heaters will not work without the fan turned on), as a precautionary measure the thermostat, which is located in the dryer compartment, should be in the OFF position before the fan is energized. Also, the main drive should be ON and the speed control set at 5 feet-per-minute (idle speed) before the heaters are on. If this is not done, the drive belt in the dryer may become excessively brittle and crack.

Two switches can be used independently of the others, provided there is water flowing into the wash tank. One is the *replenisher pump switch*. This switch can be set in the automatic position to adjust the film detection microswitch and in the manual position to adjust the replenisher flow rate or to TOP OFF the processor tanks when necessary. The other switch is the *developer recirculation pump switch*. This switch also controls the developer heater circuit. The desired developer temperature is set using the developer thermostat control knob. Once this control is set, readjustment should not be necessary, unless a malfunction in the system occurs. If it becomes necessary to raise the developer temperature a large amount, as may sometimes be the case in cold climates, the recirculation system (heater) may be operated without the main drive, dryer, etc.

All other operating controls on a Versamat have a direct relationship to one another; the speed control and main drive, main drive and water pump, dryer fan and dryer thermostat, dryer and main drive, etc. As a result, care must be taken in the order in which these controls are turned on.

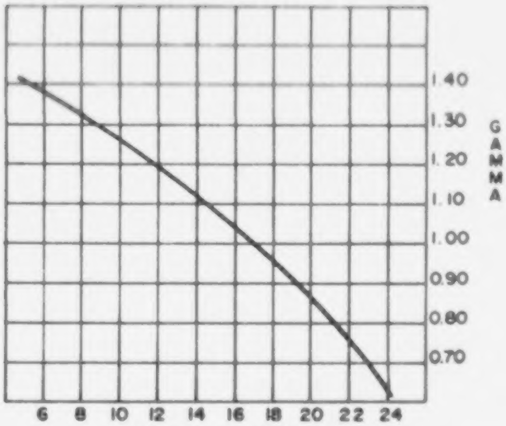

Figure 2-1. Typical machine speed gamma chart.

The basic sequence (excluding developed recirculation and replenisher pumps) with all systems turned OFF is as follows: water-main power-main drive-speed control-dryer blower-dryer thermostat. Deviations from this sequence could damage the processor.

Exercises (404):

1. If the main drive switch is turned on before the last wash tank is at least one-half filled, what might result?

2. What would happen if the main power was turned on while the main drive was on and the speed control set at 20 feet-per-minute?

2-2. Transport Speed

One of the prime operator considerations is that of processor transport speed. Unlike sheet film processing, where developing time is considered in minutes and seconds, continuous processing developing times are considered in feet-per-minute. Even though different terminology is used, both methods are concerned with the length of time the film is subjected to the developer.

405. Given a machine speed gamma chart and desired process gammas, determine the operating speed necessary to produce the desired gamma.

Transport Speed. The time that the solutions are allowed to act on the film is determined by the speed at which the machine moves the sensitized material and by the number of feet of film contained in a particular tank. In most machines, the travel speed of the film is given by an indicator which shows the number of feet of film passing through the machine per minute. Thus, the number of feet-per-minute of travel and the specific number of feet in a given section of the machine determine the development time, fixation time, washing time, and drying time. For example, if the speed control knob is set to 10 feet-per-minute, a certain point on the material being processed will take 3 minutes to go from where it enters the developing tank, if the tank contains 30 feet of film. Thus, there is a correlation between the rate of travel, the tank capacity, and the developing time. We can state the problem another way. If the tank contains 30 feet of film, the developing time at 10 feet-per-minute (fpm) is 3 minutes.

Figure 2-1 shows a typical machine speed gamma chart. This chart represents the process gamma that can be expected when all processing variables are constant, except for machine speed. For example, a process gamma of 0.70 would be produced by a machine speed of 23 feet-per-minute. A separate chart must be produced for each set of variables (machine, chemistry, temperature, etc.).

Exercises (405):

Use figure 2-1 to determine the machine speed necessary to produce the following process gammas:

1. 1.10.

2. 0.85.

3. 1.35.

4. 1.00.

5. 0.75.

2-3. Water Temperature and Flow Rate

Another important processing consideration is that of the wash water. Not only is the temperature important, but also the flow rate. Two aspects of the waterflow rate must be considered. These are (1) sufficient flow to insure complete material washing, and (2) control of the waterflow to preclude wastage.

406. Given film defects that can be related to improper wash water temperature or flow rate, determine if the defects were caused by improper temperature, insufficient flow rate, or both.

Wash Water Temperature. The importance of material washing has previously been discussed in Volume 2 of this

CDC. Therefore, we will review only those important facts relating to wash water temperature at this time. However, it must be remembered that the other washing factors previously discussed in Volume 2 also apply to machine processing.

In any photographic processing cycle, two factors relating to material washing are of special concern. The first of these is the temperature of the wash water. Most photographic materials are most effectively washed when the temperature of the wash water is 75°F. However, care must be exercised during machine processing since, in many instances, higher solution temperatures are used to speed up the processing cycle. When such is the case, the wash water temperature should also be increased since pronounced differences in the temperatures of the developer-wash-fixer sequence will cause emulsion reticulation.

If the temperature of the wash water is allowed to drop to a temperature of 65°F. or below, not only is the possibility of reticulation increased, but emulsion staining may also result. This is due to the fact that as the temperature decreases, less emulsion swelling occurs, retarding the effective penetration of the emulsion by a fresh supply of wash water. This condition also restricts the migration of chemical-laden water to the emulsion surface. When this happens, sufficient quantities of chemicals remain in the emulsion to eventually cause stains.

Wash Water Flow Rates. The other factor that is important when considering continuous processing operations is the waterflow rate.

The waterflow rate must be such that the materials are sufficiently washed. If insufficient waterflow is allowed, not only will crystallized chemicals become apparent on the material surfaces, but additional stains will result. However, most continuous processors are constructed in a manner to allow the use of much more water than is actually needed. Furthermore, most of us have a tendency to use excessive amounts of water to insure that the processed material has been sufficiently washed. This act can be extremely costly. Consider for a moment a high production laboratory consisting of 10 processors that operate an average of 20 hours each day, 7 days each week. Over a period of 30 days, if 10 gallons-per-minute flow rate is used, the total water consumption is 3,600,000 gallons. If only one-half of this amount is actually needed to wash the material, the savings is sufficient to equal the entire bodily needs of 100 people who live to an average age of 65.

From the above information, it can be seen that while a few extra gallons-per-minute flow rate may not seem important, its effect can be great. Tests should be conducted to establish the required flow rate to insure archival quality. This amount should definitely be used, but no more.

Exercises (406):

Listed below are photographic material defects that might result from improper wash water temperature or flow rate. Decide if these defects are most likely the result of incorrect temperature, insufficient flow rate, or both:

1. Reticulation.

2. Dried fixer on the material.

3. Stains.

2-4. Selecting Processing Solutions

The selection of the correct processing solutions is just as important for continuous processing as it is for sheet film processing. Even though you, as an operator, have very little to say about the type of chemistry you use in your processing machine, you should have sufficient knowledge of the different chemistries to carry on an intelligent conversation with those personnel whose job it is to select the correct chemistry.

407. Specify how different processing solution characteristics affect the final product quality.

Influence of Solution Characteristics. In black-and-white continuous processing, the type of developer used is determined by the type of product being processed. In most cases, because of the relatively short developing times and high operating temperatures, these solutions are specially formulated. If you consider a high-speed processor designed to develop high-altitude aerial reconnaissance original negative film to acceptable densities and gammas in 2 minutes or less, then you can understand why the selection of correct processing solutions is important.

Most developers are classified as either low, medium, or high contrast developers. This classification holds true only when the processing method for which the developer was designed is used. In other words, a low contrast "Versamat" developer will produce extremely high densities and contrast when used for tray processing at normal tray processing times. Likewise, if a high contrast, highly active developer designed for tray processing of sheet film is used in the "Versamat," the negative would not be usable because of the low or nonexistant densities. Therefore, to be used with the "Versamat," several companies have produced special chemistries for photographic products such as x-ray films, ground-level photography, low-, medium-, and high-altitude aerial reconnaissance, and duplicating products. For best results, each developer should be used with the product for which is was designed.

Exercises (407):

1. A low contrast "Versamat" developer, when used to tray process sheet film would be considered a (high/medium/low) contrast developer.

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2. Since atmospheric haze decreases scene reflectances, high-altitude aerial reconnaissance original negative film should be developed to a high gamma. Could a high contrast conventional developer be used in the "Versamat" to process this film?

408. Given an undesirable condition in processed material, state the cause of this condition.

Changing Processing Variables. A "Versamat" developer will produce an image on any exposed photographic material. However, in imagery production laboratories, just an image is not sufficient. The characteristics of the product must be such that complete interpretation is possible, and in the case of duplicating, all intelligence information is retained, or even enhanced. Extremes in densities and density ranges not only decrease the effectiveness of interpretation, but also, when these conditions exist in original negatives, consider the following situation:

An aerial mission is to be printed on paper-base material. This paper-base material is capable of reproducing negative density differences of 1.20 maximum. Assume that the original negative density range between useful minimum and maximum densities is 1.40. Can all of the intelligence information in the negatives be retained? The answer, of course, is "No." If the original negatives were duplicated to a positive, and then to a duplicate negative, and each generation processed to a gamma higher than 1.00, the density range is increased even more. Therefore, in this situation, a developer that is capable of producing gammas less than 1.00 must be used if the intelligence information is to be retained.

Exercises (408):

1. State the factor related to material processing that is probably the cause of a negative density range being too great to be completely reproduced on a paper-base printing material.

2-5. Solution Temperature

Another variable that must be closely monitored and precisely controlled, if repeatable results are to be obtained, is the temperature of the processing solutions.

409. Given a list of photographic characteristics, determine if increased or decreased solution temperature caused the particular characteristics.

Temperature. One of the critical elements in the control of the photographic process is temperature. The speed of chemical reaction increases as the temperature of a solution is raised and decrease as the temperature is lowered. This means that higher densities and contrast will result as the temperature increases and that lower densities and contrast will result as the temperature decreases. In machine developing, the temperature may vary, depending on the machine and the kind of processing being done. High-speed processing machines operate at quite high solution temperatures. Temperature control is critical and must be maintained at a close tolerance to produce correctly developed results. In many machines, the solution tanks are immersed in a temperature-controlled water jacket, and controlling the water temperature controls the temperature of the solutions inside the tanks. In other machines, the water jacket is eliminated, and the solution temperature is directly controlled by separate control units in the recirculation system. A temperature probe in the solution tank transmits an appropriate signal to the control unit. In spray processing, such external heating or cooling is also used to insure that the temperature of the solution (as it is expelled from the spray head) is correct.

Exercises (409):

Determine if increased or decreased solution temperature is responsible for the following effects:

1. Increased contrast.

2. Increased highlight density.

3. Decreased contrast.

4. Decreased highlight density.

2-6. Replenishment

All other processing variables can be precisely controlled, and yet the mission film is lost because of a haphazard or nonexistent replenishment program. Let's now discuss replenishment, what it does, and how it is accomplished.

410. Explain what effect replenishment has on final photographic quality.

Purpose of Replenishment. With a central reservoir recirculation system, you are using extremely large quantities of the various solutions. However, even considering the enormous quantities involved, individual chemical constituents are used up at varying rates. In addition, there are certain reaction byproducts which form in the tank. For example, bromide (a restrainer) gradually builds up in the developing solution. Also, there is a certain

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amount of carryover of solutions from one tank to another. Thus, you have a continuous change in solution strength and solution purity. To correct this, you must institute a system of replenishment. The solution used for replenishment must be compounded so that it will replace the used chemicals of each solution in correct proportion, and, at the same time, dilute the chemicals which have built up. Also, since a certain amount of fluid is lost by carryover and evaporation during processing, it, too, must be compensated for during replenishment.

The quantities of each replenisher component must be precisely controlled. Each constituent has the identical effect on the material being processed that it has in the basic solution formula. That is, too much developing agent in a solution where the quantity of the other components is correct will result in an increased product density, contrast, and base fog, for any given combination of time, temperature, and agitation. Likewise, too little accelerator in the replenisher solution will result in decreased densities and gamma due to the decreased activity of the solution.

When replenishment and recirculation procedures are used, your system must include some type of solution filtraton device. Dirt particles can enter the system during film entry, solution recirculation, and solution replenishment. These particles must be continually and completely removed. (In addition to dirt particles, chemical residue or even bits of processed material may enter the system and deposit themselves on the surface of the film being processed, unless they are filtered out.) Continuous filtration, rather than batch filtration, is generally preferable. There are many types of filters, such as cartridge, bag, or diatomaceous earth filters, which may be used. If the earth-type filter is used, it is generally used in conjunction with a cartridge-type filter installed between the earth-type filter and the entry part of the tank. The cartridge filter guards against the possibility of the earth filter breaking down and injecting abrasive particles into the system.

Exercises (410):

1. What factors must be considered in compounding a developer replenisher formula?

2. What would be the effects on photographic negatives if the replenisher was formulated:

   a. To include potassium bromide?

   b. With too much accelerator?

411. Explain the advantages of the "bleed" system of replenishment.

The "Bleed" Replenishment System. In large-scale processing operations involving continuous processors (for rollfilm) having large capacities (up to 100-gallon solution tanks), replenishment of developer and fixer is a necessity. It is not economical or practical to use a developer to its exhaustion point and then discard it. Photographic quality is degraded long before the exhaustion point is reached. In Air Force imagery production laboratories, photographic quality must be maintained with a controlled and monitored replenishment system.

Although we know that there is no absolutely constant process of any kind (it is only a matter of detecting the variations by suitably accurate measurements), it is possible, through a properly formulated and used replenisher solution, to obtain developer solutions whose photographic activity varies only negligibly over extended use. Theoretically, there is no limit to the usable life of such a properly replenished developer. In practice, the limitations on length of developer use are often physical or mechanical, such as the need for equipment maintenance, cleaning, etc.

Ideal replenishment involves the continuous replacement of significant chemical components of the developer at the same rate at which they are exhausted.

So far, the "bleed" system offers the most advantages over any other system of replenishment. In this system the replenisher solution being added to the machine process forces a proportional volume of used developer out through an overflow in the developer compartment. This system replaces the solution being carried away by the film traveling through the machine, and it also eliminates some of the unwanted byproducts formed during processing.

Exercises (411):

1. Name two advantages of the "bleed" system of replenishment.

412. Given replenishment charts, determine the rate of replenishment according to film width and processing speed.

Replenishment Charts. In many imagery production laboratories, replenishment charts similar to the hypothetical one shown in figure 2-2 are used. These charts, established for each processor and each film/developer combination, are used as a quick reference for determining the average replenishment rates for normally exposed material. You must know that any time original aerial reconnaissance negatives are predominately cloud cover or dense foliage, the indicated replenishment rate will not be correct.

As you can see from figure 2-2, these charts indicate the replenishment rate in milliliters-per-minute according to film width and processor transport speed. In this figure, the

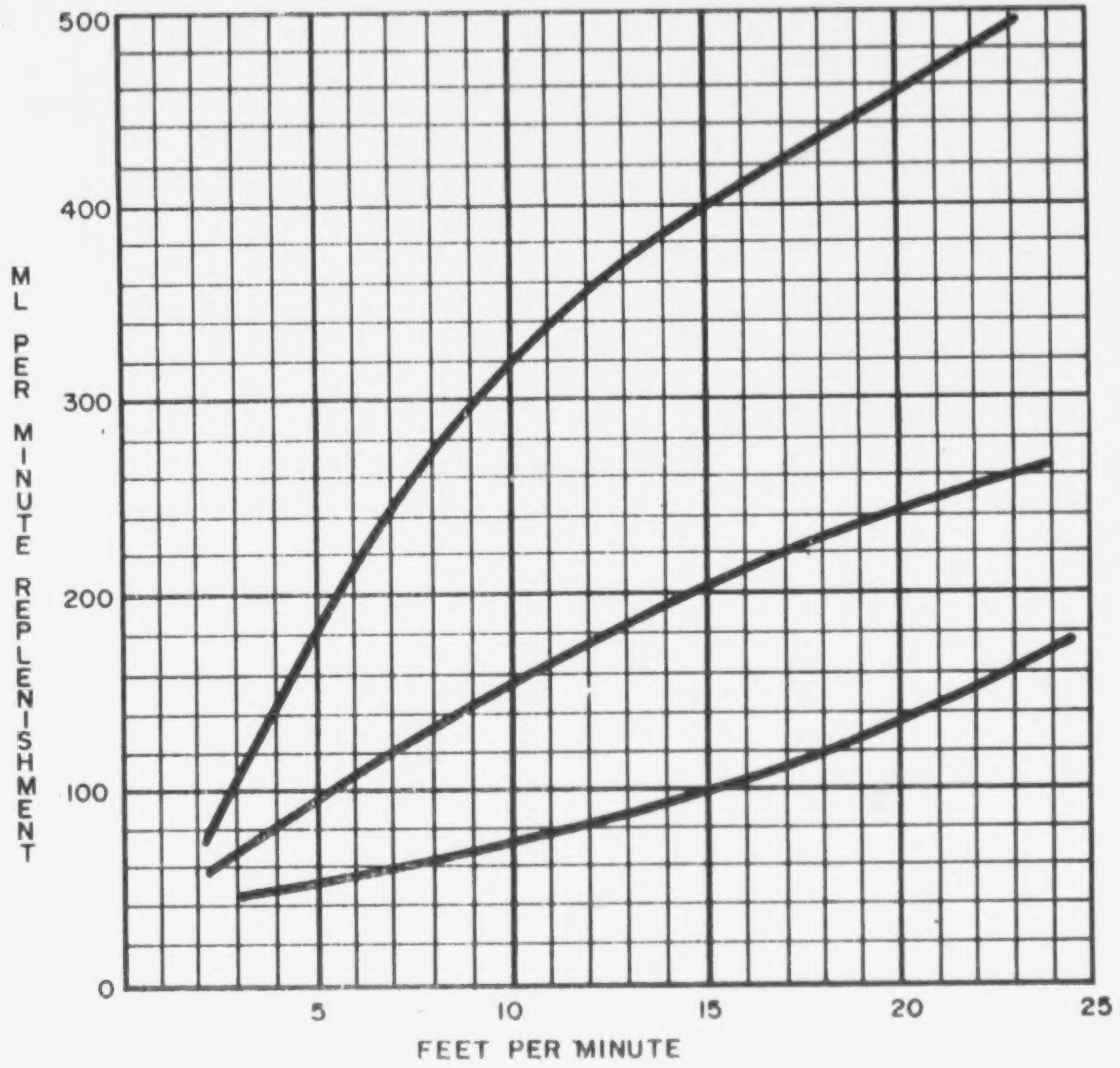

Figure 2–2. Replenishment chart.

bottom line represents the replenishment rate for 70-mm film, the centerline for 5-inch film, and the topline for 9½-inch film at 10 fpm which follows:

(1) Locate the processor speed along the horizontal axes (10 fpm).

(2) Go up the chart, following the line which represents the processor speed, until that line intersects the line representing the width of the film being processed (9½ inches or topline).

(3) Follow this line of intersection to the vertical axes. The value at that point is the replenishment rate (320).

Since most processor flowmeters indicate replenishment rates in arbitrary quantities, a correlation between the actual flow and the indicated flow rate must be established. For this correlation, a separate correlation chart must be constructed.

Exercises (412):

Using figure 2-2, determine the approximate replenishment rate in milliliters-per-minute for the given information:

Film Width	*Transport Speed*
1. 70 mm	20 fpm
2. 9½ inches	17 fpm
3. 70 mm	19 fpm
4. 5 inches	13 fpm
5. 9½ inches	16 fpm
6. 9½ inches	14 fpm
7. 5 inches	18 fpm

2-7. Dryer Temperature

The rollfilm processing machines we discussed normally include drying cabinets. After the material has been developed, fixed, and washed, it continues through the machine into the drying cabinet where the moisture is removed. It emerges from the cabinet in a dry condition and is spooled onto a reel.

413. State requirements and factors relating to machine-drying; and given a list of film conditions that can be related to improper drying procedures, indicate if the drying temperature was too high or too low.

Dryer Temperature. The drying cabinet is much more than a heated container for the sensitized material. In a majority of machines, both the temperature and the humidity of the cabinet are controlled so that the completely processed material has the desired properties. Too little drying causes the emulsion to be tacky; whereas, too much drying produces excessive curl and brittleness. Both the temperature and the relative humidity of the air supplied to the drying cabinet must be carefully controlled and adjusted for the speed at which the machine is operating.

The drying of film is a complex operation. So that moisture may be removed from all depths of an emulsion, it must first migrate to the surface and then evaporate in the air. The rate at which this takes place depends upon the thickness of the emulsion, the amount of hardening the emulsion received, the density of the developed image, the air temperature, the relative humidity of air (RH), and the movement of the ambient air reaching the film.

Some integral processing machine dryers contain infrared heating lamps working in conjunction with blowers. There are holes in the cabinet for the passage of the dry incoming air and the wet outgoing air. The most sophisticated machines usually are an impingement-type dryer, using high air velocities directed against the surface of the film. Air impingement systems require precise control of temperature and humidity.

The most common machine-drying method is called impingement drying. In this method, jets of air are applied at right angles to the emulsion and base surfaces of the film simultaneously. The air is heated to dry-bulb temperatures ranging between 100°F. and 150°F. and is directed against the film at velocities from 5000 to 6000 feet-per-minute. An efficient air or roller squeegee must be used since surface liquid remaining on the film produces nonuniform drying. As with any other type of dryer, the conditions of temperature and velocity must be adjusted to the local climate. Otherwise, the film will dry more rapidly at the edges with the usual undesirable effects previously mentioned.

Parallel-flow dryers consist of a series of reverse-bend ducts to conduct warm, dry air across the film as it moves through the drying cabinet. In order to prevent drying marks, parallel-flow dryers should be operated at rather high velocities. The temperature should not be excessive, and the relative humidity of the air should not be too low. The exact conditions must be adjusted to the climate in which the dryer is being used. Different settings would be required for coastal areas than, for example, the Arizona desert.

Some processors, particularly the earlier motion picture processors, employed radiant heat in their dryers. In some cases, radiant heat panels are used; in others, infrared lamps are the source of heat. This system must also include some method of moving the air, or else it will soon become saturated and drying will not take place. Attempting to increase the drying rate by increasing temperature generally results in blistered emulsions.

Exercises (413):

1. The rate of machine-drying of film depends on what factors?

2. Describe the basic requirements of an impingement drying system as used with a processor.

3. What drying condition could result in the following produced conditions?

   a. Emulsion blisters.

   b. Drying streaks.

   c. Tacky emulsion.

2-8. Dryer Humidity and Airflow

Under ideal drying conditions, the drying cycle should yield film having a moisture content in equilibrium with air at about 50 percent relative humidity. The film is in equilibrium when it has no tendency to give up moisture to the air or to take on moisture from the air.

414. Given problems encountered when dryer humidity is not satisfactory, indicate whether the problem can be related to dryer humidity that was too high or too low.

The Drying Process. During the drying process, the air is heated to expand it, to lower its relative humidity, and to accelerate the evaporation of moisture. These last two factors are directly proportional to the temperature. The temperature must be held within certain limits. If it is too low,, evaporation is slowed up; and if it is too high, the emulsion may be damaged. The exact limits are governed by the kind of material being dried, how it was processed, and the type of dryer being used.

As previously stated, the air must be in continuous motion. The main reason that the air should be kept moving is that the air at the surface of the wet emulsion soon becomes saturated and cannot take up the additional moisture. This saturated condition of the air usually results in the material not drying sufficiently. When this happens, most emulsions will feel tacky. The saturated air must be replaced by unsaturated air if drying is to continue. Of course, even so-called "still air" is in constant motion, and an emulsion will dry eventually, but the drying will most likely be uneven. When warm, dry air moves too slowly across a film, the film tends to dry more rapidly at the edges than in the center. Thus, visible lines may appear as a result of these wet-dry borders. This condition is apt to occur in some types of parallel-flow dryers.

Some types of film tend to become excessively brittle when dried rapidly. This is due to reduced relative humidity rather than overdrying. When this occurs, moisture retaining additives may be introduced into the final rinse, and/or the temperature and RH of the air adjusted to permit slower drying. Brittleness cannot be eliminated once it occurs; and since it cannot be corrected, it must be prevented.

Exercises (414):

Indicate whether the following product conditions can be related to insufficient or excessive humidity during drying:

1. Brittleness.

2. Tacky emulsion.

3. Uneven drying.

2-9. Processor Solution Levels

Another factor of prime concern to the operator is the solution levels in his or her processor. The quantity of solution can be decreased both by evaporation and carryover. Since solution carryover accounts for a much greater loss of solutions than does an evaporation, we will restrict our discussion to this factor.

415. Given hypothetical situations concerning improper solution levels, indicate the effect these situations would have on photographic quality.

Solution Levels. We mentioned previously that there is a certain amount of carryover of solution from one tank to another within the machine. Usually, chemical carryover is minimized by use of mechanical rubber roller squeegees. Air squeegees are generally used at the end of each wash operation to prevent carryover of contaminated water to a subsequent wash and to remove surplus water before the film enters the drying cabinet. If this water is not removed, or if it is only partially removed, drying streaks are apt to occur on the finished product. On some machines, air squeegees may be used between two tanks containing different processing solutions if the air impingement (i.e., the high-pressure air striking the surface of the film) caused by squeegee operation will not affect the efficiency of the solutions through oxidation.

In most systems, the air squeegee is simply a narrow slit through which a large volume of air passes under pressure. By forcing air against the surface of the film in this manner, most of the liquid being carried on the surface is forced back into the tank from which it came. All squeegees must operate properly if an accurate replenishment rate is to be maintained.

Anytime that high-velocity air is being directed against a piece of film, as it is with air squeegees, you must make sure that the air being supplied to the squeegee does not contain any dust, moisture, or oil. Therefore, the supply must be filtered. A filter which can remove oil is especially desirable if the air compressor is oil-lubricated. (If there is a choice, use air compressors which do not require oil for lubrication.) Air filters provided with the machine should be cleaned or changed often enough to insure that completely clean, dry air is being delivered to the air squeegee.

The developing time required is directly proportional to the depth of developer in the tank. Thus, you see how important it is that the proper solution levels be maintained.

Exercises (415):

1. The air squeegee between the wash and fixer tanks on a continuous processor stops operating during processing:
   a. What will be the result of this malfunction?

   b. What will probably happen to the film being processed if corrective action is not taken immediately?

2-10. Transport Mechanisms

In most imagery production facilities, large quantities of material are processed daily. At present, there are only two general types of processors in wide use. These are (1) the nonleadered ("Versamat") type and (2) the leadered type which use leader material to guide or pull the photographic material through the solutions. In this section we will discuss both types.

When the leader-type processor is used, some method for attaching the unprocessed material to the leader or other unprocessed rolls must be available. There are several ways that these materials can be spliced together. However, at this point, we are concerned only with two. These are the *tape splicer*, common to most wide film processors, and the *stapling method* which is generally accepted for splicing narrow film.

416. State the importance of the various tasks required for certification of the splicer assembly.

Wide Film Spilcing. The film splicer is an intergral part of the processor. It is installed on top of the power section. This splicer assembly consists of a cutting platform, a film-cutter assembly, a film lock, a tape dispenser, and a tape cutter. Components are installed in a lighttight inclosure fitted with an access door.

Automatic interlocks and warning devices are incorporated to prevent film breakage or accidental exposure and to warn you of malfunctions. The magazine is retained by means of a locking flange on the film splicer. A plate engages the locking flange of the installed magazine; thus, the magazine is locked securely against the splicer.

Film enters the splicer through a slot below the locking plate. It travels across the cutting platform and through a spring-loaded clamp-type film lock. The film lock prevents the end of the roll from passing into the machine tanks by firmly clamping the film and holding the film end stationary for splicing. If the film lock does not function properly and the film end passes into the machine tanks, the processor will have to be releadered before processing is continued. By turning the splicer handle to the OPEN position, the film lock, which also acts as a light trap, is closed. (The film lock is closed by springs and provides a light trap.) When the access door handle is turned to the CLOSED position, the film lock opens, allowing the film to pass through.

Linkage from the access door handle also engages the light trap opening pin on the front of the magazine locating plate. Turning the access door handle depresses the pin and opens the light trap simultaneously with the splicer film lock. Turning the handle to OPEN (or removing the magazine from the splicer) allows the pin to reextend and to close the light trap. The access door handle should always be placed in the OPEN position when film is not being processed to deenergize certain electrical components.

The film lock, which is operated manually by the access door handle, is also operated automatically when the end of the film in the magazine reaches the film splicer. A small roller, linked to a limit switch on the wall of the splice box is held up by the film passing below it. As the film end passes, the roller drops into a slot and actuates the switch. Actuation of this switch energizes the film lock solenoid. Linkage between the solenoid and the door handle unlocks the splicer door and thereby closes the film lock as well as the magazine light trap. At the same time, the limit switch energizes the yellow warning light on the control panel (and the warning horn in the power section) to alert you that the end of the film has been reached. (This limit switch also deenergizes the load-accumulator elevator brake.)

A second limit switch on the splice box wall is actuated when the access door is raised. When this switch is actuated, the warning horn shuts off; however, the yellow light remains on until the film supports the film switch in the splice box. The solenoid, however, remains energized until more film is fed into the splicer box from a new magazine. This newly supplied film lifts the splicer end-of-film switch roller out of its slot. Releasing the solenoid, however, does not open the splicer film lock. The door handle must be returned to the CLOSED position to reopen this lock.

A defect in the yellow panel light or warning horn might result in the operator not being warned that the end of the film has been reached. Such a situation would result in the entire amount of film in the accumulator section being transported into the developer. When this happens, most processors will automatically shut off.

The film cutter slides on the rails of a cutter-arm assembly and has a rotary cutting blade. This blade must be free to rotate axially and is extended for cutting by pivoting the blade arm forward. If the blade does not turn freely, a clean cut will not be obtained. Jagged or torn film cuts will not allow splices to be made that can withstand the stresses encountered during processing. The film is cut as the cutter arm slides forward on the rails. The cutter-arm assembly is pivoted to swing upward, permitting access to the cutting platform. When lowered into the cutting position, the arm aligns the cutting blade with the slot in the cutting platform through the action of two clips attached to the platform. The arm is secured in place by a latch. When the latch is released, a spring holds the arm in a raised position.

A tape dispenser, holding a roll of splicing tape, is mounted on the back wall of the splicer. Tape is pulled off the roll over a roller at the back of the cutting platform. It is retained against this roller by a holddown roller just above it.

A tape cutter, mounted on the back of the cutting-arm assembly, contains a chambered center-bit cut blade in a spring mount. The blade is attached to its retainer with screws for ease of replacement. A spring-mounted stripper on the blade retainer covers the blade edge when it is not in use.

Exercises (416):

Certification of the splicing assembly includes the following tasks. Explain what might happen if these tasks are not performed correctly.

1. Insuring proper operation of the film lock.

2. Insuring the operation of the yellow panel light and warning horn.

3. Verifying that the cutter blade turns freely.

4. Checking the quantity of splicing tape.

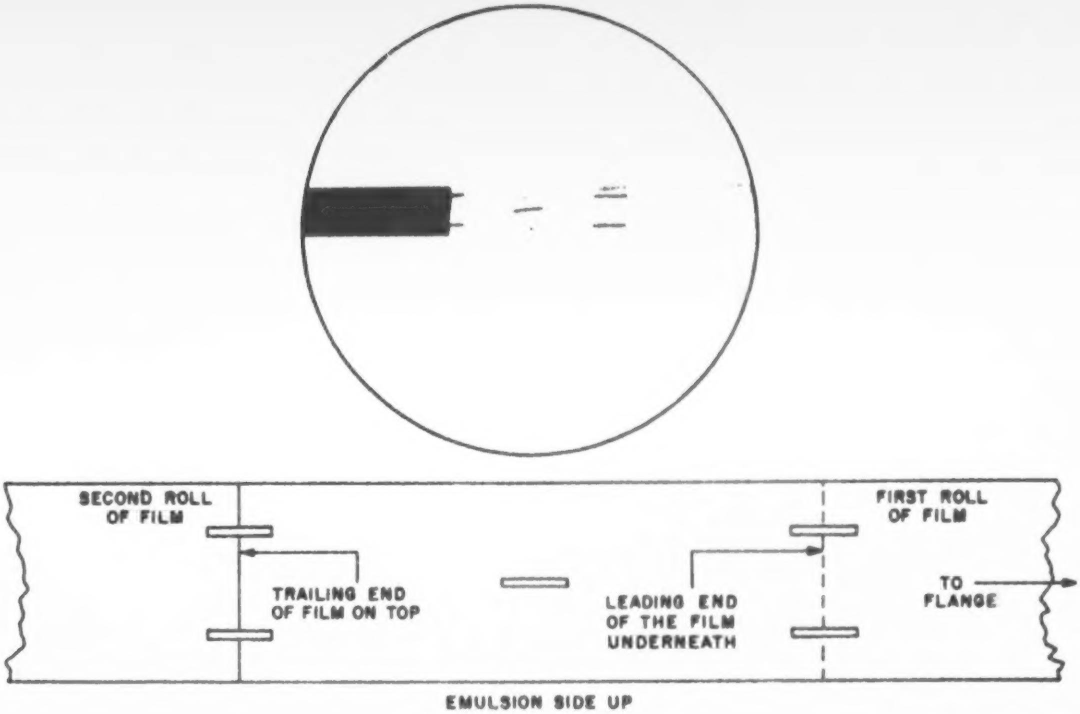

Figure 2-3. The five staple film splice.

417. Specify the possible processing results from improper splicer operations.

Narrow Film Splicing. The splicing assembly described in the preceding paragraphs would be of very little use for narrow film splicing. For this reason, staples are most often used.

When you are splicing narrow film together, overlap the ends of the films about 1½ inches and secure them with a splice consisting of five staples. Figure 2-3 illustrates the five-staple splice, known as the 2–1–2 splice. In making the splice, place the trailing end of the film on the magazine flange over the leading end of the film on the camera spool. As the film comes out of the magazine and goes into the processor, the leading edge of the splice will then be on top, allowing it to pass over the outside of the rollers during processing. This lessens the chances of splice damage or breakage.

The handiest stapler to use in the splicing operation is the plier-type stapler. This is shaped like a pair of pliers with the stapling end in the nose portion. To make the splice, position the split nose of the stapler over the film where you wish to place the staple; then squeeze the handles of the stapler firmly together as far as they will go. After you have the staple in place, check to make sure that it is not bent or broken. Any sharp ends can catch against a roller and tear the film.

Exercises (417):

What might happen during processing if the following things occurred during splicing?

1. The trailing end of narrow film on top.

2. One of the staples not closed properly, exposing a sharp end.

418. Specify how selected processors are adjusted for different film widths.

Difference Between Wide and Narrow Film Processors. From the standpoint of film width, continuous processors are generally classified as being wide film or narrow film processors. Wide film processors, those that

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handle film up to 9½ inches wide, are equipped for the over-under type threading. That is, the film passes over the top roller and under the bottom roller. There is no material loop formed by this system.

These wide film processors are constructed so that each roller is wider than the widest film that will be processed on the machine. Since there are no film guides on each roller, sufficient room must be available to allow the film to oscillate randomly without the danger of the film becoming caught in the drive clutches or gears. No physical adjustments for different film widths are necessary for this type of processor. In most cases, the path that the film takes through this machine is determined by the position of the film supply within the processing magazine.

Narrow film processors pose a different set of problems. First, to conserve space and keep the processor as small as possible, loop-type threading is used. This requires that each film roller has film guides to keep the material in the desired travel path.

Most of these narrow film processors are delivered with rollers designed to accommodate both 16- and 35 millimeter film. However, one processor in particular is delivered with rollers capable of handling 16-mm film only. For laboratories responsible for processing both 16-mm and 35-mm film, this problem is solved by replacing the 16-mm spools with the combination 16-mm and 35-mm spools provided with the processor.

Exercises (418):

Determine if adjustments for film width need to be made on the following processors. If so, explain how the adjustments are made.

1. "Versamat" (maximum film width is 9½ inches).

2. "Fultron" (maximum film width is 9½ inches).

2-11. Mechanical Certification of Black-and-White Processors

As you realize by now, there is no room for error in any operation conducted by an imagery production laboratory. Much of the laboratory equipment used is highly sophisticated and complex, specific procedures must be followed carefully, and personnel must be proficient. If you were the pilot of an aircraft, you would follow a preflight checklist to make sure that all instruments read normal values and that all controls are operable. During flight, you would continuously monitor your instruments to minimize the possibility that something could go wrong. During and after landing, you would follow another checklist to land and shut down the aircraft. Such techniques are also appropriate to photographic equipment and procedures. Mechanically certifying a processor requires that you process a scratch test and verify all functions before mission film is processed.

419. Cite the reason for conducting mechanical certification tests.

Scratch Test Production. During machine startup, you are, in reality, certifying that all processor systems are operating properly. If unusual noises, or inoperative pumps, motors, etc., are found, they are repaired or replaced before processing begins. But just because all processor systems operate properly does not guarantee that the product will be free of physical defects produced by the processor.

Basically, mechanical certification consists of processing a quantity of flash film. Flash film is raw film stock that has been exposed to simulate the overall density of mission film (usually, a density of 1.00 to 1.20). If any defect that could have been produced by the machine is evident upon examination of the flash film, the machine is shut down until the cause of the defects can be found and corrected.

Exercises (419):

1. Why must mechanical certification tests be conducted on continuous processors?

420. Given image degradations that are produced during mechanical certification of black-and-white processors, determine the probable cause and indicate possible corrective actions.

During examination of the processed flash film, it is checked for developing and drying streaks, development mottle, scratches, abrasions, pinholes, etc. The presence of any such defect indicates that the processor is not operating as it should. As an example, drying streaks could result from two common sources. These are improper squeegeeing or blocked airflow in the drying compartment.

Scratch Test Analysis. The defect most often found during mechanical certification is scratches. The cause of scratches is also the most difficult to find. After processing, the scratch test could contain scratches from a number of sources. Some of these are the printer used to expose the film, cinching the film, the processing magazine, and the processor itself, only to name a few.

The method most often used to determine if the scratches are produced by the processor is quite simple. This method consists of cutting a short length of the flash film from the center of the strip, turning it, and resplicing it into the strip before processing. The degree of turn may be either 90° or 180°. There is one disadvantage to both turns, however. On the 90° turns, the length of film that is spliced back into the strip must be the exact width of the flash film. During analysis of the 180° turn, some scratches not produced by the processor may match perfectly and falsely indicate that they were produced by the processor. In most cases, however, scratches on both turns that are continuous might have been produced by the processor. All others may be ignored during processor certification.

Exercises (420):

1. What would possibly cause gouges in a straight line within the emulsion every 3 inches on the scratch test, including the turnaround portion?

2. What would probably be the cause of drying streaks produced during mechanical certification of black-and-white processors?

2-12. Mechanical Certification of Color Processors

As with black-and-white continuous processors, color continuous processors must also be mechanically certified prior to processing mission film. Therefore, let's discuss the mechanical certification of the color "Versamat."

421. Given image degradations that are produced during mechanical certification of color processors, determine the cause of each.

As with black-and-white processors, mechanical certification of color processors consists of performing processor startup and processing a length of raw stock film. Unlike black-and-white processor certification, however, the raw stock film used for scratch tests on color processors is not given a flash exposure. While this helps preserve the quality of the color processing solutions, it makes evaluation of the scratch test more difficult.

In evaluating the scratch test, the film must be examined by reflected light on both the emulsion and base sides. If a scratch appears and there is doubt as to whether it was a result of the processor or some other factor, rerun the scratch test following the turnaround procedures outlined for black-and-white processor mechanical certification. If it is determined that the processor is causing the scratches, a table similar to table 2-1 can be used to help locate the cause of those that are repetitive.

Exercises (421):

1. Processed mission film contains repetitive emulsion abrasions approximately 8 ⅓ inches apart. These abrasions did not show on the scratch test. Could they be caused by the processor? If so, determine from table 2-1 what roller could cause them.

2. Abrasions appear on the emulsion of the scratch test at an interval of approximately 2.7 inches. What could cause these abrasions?

2-13. Chemical Certification of Black-and-White Processors

Another certification done before processing mission film concerns the quality of the processing solutions. While the analysis of the chemical certification data is the responsibility of quality assurance personnel, you, as the operator are responsible for providing the necessary input data.

422. List the tasks that must be performed during chemical certification.

Chemical Certification Tasks. At this point in your career, you should know that both the developer and fixer must be certified prior to processing mission film. Such checks as pH and specific gravity may be made each day during startup. Some laboratories also perform these checks at regular intervals during the day or after a given quantity of film has been processed. Sensitometric strips are also processed at the time of certification, and at regular intervals during the day. Data from these checks are maintained on control charts for each processor. If the first sensitometric strip falls within the control limits, but is near one of the control limits, it is foolish to assume that the machine is chemically certified. A second, and even a third strip should be processed, depending on criticality of mission film. Most laboratories process flash film during machine certification with sensitometric strips spliced within the flash film at regular intervals. Each laboratory has its own chemical certification standards. However, if the required footage of flash film has been processed, and the sensitometric strips are within control standards, and if chemicals meet pH and specific gravity standards, the machine can be said to be chemically certified.

At times, the operator may not be able to bring his or her machine into chemical control. When this happens, the only alternative is to drain the chemicals, refill the machine with fresh chemicals, and restart the chemical certification. If replenisher solutions have been stored for some time, they should be recertified before the machine is considered chemically certified.

Exercises (422):

1. What tasks should be performed during chemical certification?

2. List the steps the operator must take if the machine cannot be brought into chemical control.

433. Given hypothetical control chart conditions, indicate the effect these conditions will have on photographic quality.

Analysis of Chemical Certification Data. Chemical certification data, if it is to be of value to the quality

TABLE 2-1
ROLLER POSITION DETERMINATION
(KODAK EKTACHROME RT PROCESSORS, MODELS 1411-AM AND 1811-M)

Measured Distance Between Spots	Rollers of This Size Which Contacts	
(Roller Circumference)	Film Base	Film Emulsion
8.38 inches	All crossover master roller	None
6.28 inches	None	All turn around master rollers
3.33 inches	Rack Rollers, both plain and grooved	Rack rollers, both plain and grooved
3.14 inches	Dryer turn around (bottom rollers)	None
3.08 inches	Squeegee rollers A-D	Dryer turn around (top rollers)
	Dryer section roller D	Dryer entrance cross-over (A-D)
2.75 inches	Exit crossover to Squeegee	None
2.68 inches	Detector assembly (bottom rollers)	Detector assembly (top rollers)
2.29 inches	Dryer entrance crossover (B,C, and E)	Film Squeegee
	Film Squeegee	Dryer section (C)
1.96 inches	Turn around assembly (all racks)	Exit crossover section AA top
1.76 inches	None	All crossovers

assurance personnel, must be easily accessible in order of occurrence. The method most often used is to plot the data on control charts.

The control chart is a long chart on which the horizontal axis may be marked off in units of time, frequency, or some subgroup number. The vertical axis is marked off in whatever unit of value is given to your observed samples. Your process is begun, your samples are taken, and your observations chronologically plotted. After a given number of observations have been plotted, find their average and indicate it on the control chart.

When the data has been plotted on charts, the next step is to indicate the control limits. These limits may be established through statistical computations, or they may be arbitrarily established by the individual laboratory. Regardless of the method used, these limits are indicated on the chart.

Occasionally, a point may fall outside of the control limits. This does not mean that your process has gone bad. The out-of-control point may be due to chance causes. If so, your process will return to within its limits shortly. Even several out-of-control points do not indicate that corrective action is necessary. It requires 5 to 7 points to establish a trend.

Sometimes out-of-control points are due to assignable causes, meaning that there is some reason other than chance responsible for the behavior of your process. If the assignable cause remains, your process will be affected, and the cause must be removed. Once in a while an assignable cause will occur once and never be repeated. In this case, it can be considered and treated as a chance cause. Analysis of this type control chart is simple to the trained observer.

Let's assume that this chart represents process gamma. In this case, the vertical axis would be set up to include the entire range of gammas that might be obtained for a given speed and temperature combination. As an example, this range might be from 1.00 to 1.20. Next, the first test strip is processed and the gamma determined. This gamma value is then plotted as the first point on the chart to correspond to the correct gamma value. Furthermore, it is positioned to the extreme left on the chart. As subsequent tests are conducted, the resulting gamma values are plotted from left to right on the chart. After a sufficient number of entries have been made, their average is determined and this value indicated by a line on the chart (note centerline).

From this chart, we can determine what the process has done in the past, and its behavior as we enter subsequent data. As an example, by glancing at point "B," we can immediately see that the gamma at this point is higher than the average gamma of all points. The next plot to the right is low. Again, these do not indicate that these particular tests are unacceptable, only that the process is fluctuating normally.

When 5 to 7 plots run in the same direction, either upward or downward, a trend is established. These plots may be within control limits, out-of-control limits, or spanning some values that are within control limits and some that are out-of-control limits. When successive plots increase in value, in this example, something is happening in the process to cause an increase in gamma. Most often, an evaluation of the process will reveal a change in some factor that has resulted in this trend. In the case of increased gamma, such things as a decrease in machine speed, a malfunctioning solution thermostat or temperature indicator, or the use of uncertified replenisher solution should be suspected. Such a trend as described would result in increased densities mainly in the heavily exposed areas of the film.

All other control factors which are maintained on a control chart will be similarly influenced by trends. A downward pH trend, for instance, indicates decreasing developer activity and would result in decreased gamma and density. Upward and downward density trends can result from such factors as exposure and development. It should be understood that it is possible for one control chart to indicate the reason for an unacceptable condition of another control chart (high maximum density points might be explained by a corresponding high gamma point).

A control chart is maintained for each of the chemical certification tasks. Usually, in addition to those control charts for pH and specific gravity measurements, four are maintained on the sensitometric data. These four are for minimum, average, and maximum densities, as well as gamma. Some precision laboratories extend the number of charts to include such additional items as film speed, resolution, etc.

Exercises (423):

Describe what effect the following control chart conditions will have on photographic quality.

1. A control chart for pH with an upward trend.

2. A control chart for gamma with a downward trend.

3. A control chart for minimum density with an upward trend.

2-14. Chemical Certification of Color Processors

Like any photographic process, the color process is kept in control by insuring that each major phase is operating within specified tolerance limits. The certification of the color solutions, then, is an important phase of the quality control program. Since photographic materials are extremely sensitive to variations in the processing solutions, each solution should be tested and evaluated to insure its conformance to the process requirements. To verify test results, replication is advisable.

424. List the color solutions that pH values must be determined for in order for the analysis to be considered complete, and describe the effect of pH variance of the color developers.

Physical and Chemical Test. There are several tests that must be performed in the chemical certification of color processors. These are broadly grouped into three categories:

(1) Physical properties, consisting of a specific gravity test.

(2) Chemical tests, including pH (total alkalinity, total acidity, and analysis for specific components are also suggested, but are primarily the duty of quality assurance personnel and will not be discussed in this CDC).

(3) Process effect, consisting of sensitometric tests which evaluate the effect of solutions upon a sample of the photographic material.

The specific gravity test is usually the first performed and serves as a quick check to determine whether or not the solution density meets a standard. If a solution is of substandard quality it can usually be detected by the combination of the specific gravity, pH, and sensitometric tests.

In order for the test to be representative, two conditions must be met. First, the solution in the tank must be of uniform consistency and, second, samples must be obtained in a manner which precludes any possibility of contaminating either the sample or tank contents. The vehicle and utensils used to draw the sample should be thoroughly cleaned with a detergent wash, three tapwater rinses, three distilled water rinses, and a final rinse with the sample to be tested.

When making the specific gravity measurement, it is important that the temperature is carefully measured. Ideally, a water bath should be used where a constant temperature can be maintained for pH buffers and samples. This water bath could serve the additional purpose of maintaining temperatures for specific gravity measurements as well. A thermometer accurate to within 1/4° should be used and always read in the same manner.

Due to the high process temperatures of the color process, both specific gravity and pH measurements are made at 80°F. This offers a compromise since the process temperatures of 115°–125°F. are difficult to maintain outside the machine, and standard 60°F. hydrometer calibration temperature is too low to offer any validity. The most important factor in the specific gravity test is not extreme accuracy, but reliable repeatability once standards are known.

The photographic effects of most processing solutions are highly dependent upon the effective concentrations of hydrogen and hydroxyl ions. The concentrations of these two are so related that only one of the two needs to be determined. The hydrogen ion concentration is indicated by measuring the electrical potential between a glass electrode and the solution surrounding it. To measure this potential with a meter, a constant potential reference electrode is used to complete the circuit. The meter scale is calibrated in units of pH, which is defined as the negative logarithm of the effective hydrogen ion concentration.

Several factors are present in this measurement which cannot be compensated for, such as the presence of sodium ions and liquid junction potentials. These lead to a bias in pH measurements. However, a true pH value is not necessary if the relative value obtained can be reproduced within the allowable tolerance. To achieve this control, the meter, electrodes, buffers, temperature, and technique must be kept within rigid standards.

Since there are a great number of variables in the color process, it can easily go out of control. Regaining control of the processor and its associated chemistry systems is a technique that requires experience.

In the past, little has been known about this process, and when control was lost, corrective action usually meant the dumping of the solutions. More control information is being accumulated, and a procedure has now been developed to make control of the process possible through an adjustment of the temperature and pH of the solutions. The most important of the solutions in this respect are the prehardener, neutralizer, stop baths, and the developers.

While maintaining the pH of several solutions is necessary for proper color production, the three most important solutions are discussed below.

Prehardener. The degree of hardening action determines the rate at which the subsequent solutions penetrate the emulsion. If the pH of the prehardener is too high, the hardening action is increased and the photographic effectiveness of the remaining solutions is retarded. A low pH has the opposite effect.

First developer. As with black-and-white developers, the pH of this solution influences the contrast of the black-and-white negative image. If the negative image contrast is either too high or too low, improper color balance of the final product will be evident.

Color developer. The color developer pH must be carefully controlled if the blue and green control points are to be held within limits. High pH produces high blue and red points and low green points; while low pH produces low blue and red points and high green control. The pH of the color developer is likely to drop overnight because exposure of this solution to air allows it to absorb carbon dioxide. Faulty pumps or line seals, causing aeration of the developer in the recirculation system, may also cause the pH to drop.

Two solutions are used extensively to control the pH of the color developer. Seven normal (7N) sulfuric acid is used to lower the pH of the processing solution. This solution is mixed by slowly adding 200 milliliters of concentrated sulfuric acid to 500 milliliters of distilled water, cooling, and adding water to make 1 liter. Ten normal (10N) sodium hydroxide is used to raise the pH of process solutions and may be mixed by adding 400 grams of sodium hydroxide pellets to 600 milliliters of distilled water in a magnetic stirrer. Stir until dissolved, then dilute the 1 liter with distilled water. Store both of these solutions in glass-stoppered bottles near the processor. For convenience, you may prefer to use 7N sodium hydroxide instead of 10N so that equal amounts of acid or base will result in equal pH changes.

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Exercises (424):

1. What color solutions require the highest degree of pH control?

2. What will be the effect if the pH of the color developer is:

   a. Too high?

   b. Too low?

3. What will be the effect if the pH of the prehardener is:

   a. Too high?

   b. Too low?

425. Using table 2-2, determine the effect out-of-control solution conditions will have on photographic quality.

Process Effects. Sensitometric tests must be processed during chemical certification. These tests are not only used to reflect the effect of solution pH, but also solution contamination.

In order for color sensitometric tests to be of value, reference values for several test strip densities must be established. This is done by processing at least two control strips each day. This operation is repeated for several days. Thus, the average value for each set of densities is obtained. The average values of the reference readings are then entered in the appropriate places on the control chart to serve as standard levels for each of the process cycles. The control limits for these specific portions of the characteristic curve are given below:

	Step on Strip	*Density*	*Color Balance*
D-max	Step 11	−0.25 (no upper limit)	None
Shadow	Step 7	±0.15	0.13
Highlight	Step 4	±0.10	0.08
D-min	Step 1	±0.03 (no lower limit)	None

After a control strip has been processed and dried, the densities for the selected steps are measured through the red, green, and blue filters. The differences for the corresponding reference readings (subtract the reference value from the value found for the strip) are then plotted on the control chart.

After the density difference values of each control have been plotted, count the density units separating the bottom and top plotted points for steps 4 and 7. If either of the resulting values exceeds the color balance control limit for that step, mark the value underneath the plotted points.

Theoretically, all correctly processed control strips should be identical to the reference strip and should plot on the reference (0) lines. There exists certain inherent variability in any process which cannot be eliminated. It should be noted, though, that the nearer the control strips plot to each reference line, and the smaller the color balance spread, the better the quality of the process.

When a control strip plots outside the tolerance limits for either density or color balance, or when a series of control strips plot near a tolerance limit even though the control strips are within the limit, immediate investigation should be made to determine the cause:

a. Examine the control strip for physical defects, such as fingerprints, scratches, fog, etc.

b. Compare the factory code number of the Kodak control strip with that of the reference strip used to determine the reference readings.

c. Determine if the densitometer is in control.

d. Reread the control strip to eliminate measuring error as a possible cause of the out-of-control plot.

e. Process, read, and plot another process control strip:

(1) If this strip plots within tolerance limits, the previous control strip may have been handled incorrectly before or during processing. Also additive conditions may have been the cause of the out-of-control plot. When this is the case, it is very possible that the process is drifting toward an out-of-control condition. Therefore, it is advisable to process additional strips in order to confirm whether or not the process is approaching an out-of-control condition.

(2) If the out-of-control condition is confirmed by the plot of additional control strips, corrective action must be taken.

In addition to pH-caused color shifts which are generally minimal, gross color shifts are usually caused by chemical contamination. The best procedure is to establish preventive measures to guard against contamination of one solution with another. However, since the possibility exists, it is desirable that laboratory personnel be familiar with the cause of large control point shifts. Table 2-2 lists many visual indicators of chemical contamination.

Control of any color reversal process is a difficult time-consuming task which cannot be learned overnight. Each chemical change, in terms of its effect upon the imagery, must be understood and the effect of changes should be recorded. A notebook, kept neatly and completely, is the way to begin to learn the technique of color process control.

Exercises (425):

Use table 2-2 to solve the following problems.

1. What could cause the green control points to be low?

TABLE 2-2

CHEMICAL CONTAMINATION GUIDE

Chemical	Visual Appearance	Control Point Effect	Contaminated With
First & Color Developer	Very dense	All very high	Developers Switched
Prehardener	Green	G low	Fixer
First Developer	Very light & Cyan	R highest, but all low	Prehardener
First Developer	Bluish	B low	Bleach
First Developer	Very light, Cyanish	R highest, but all low	Fixer
First Developer	Light, cyanish	R highest, but all low	Color Developer
Color Developer	Very light	All low	First Developer
Color Developer	Greenish yellow	G low, B high	Prehardener
Color Developer	Very light, cyanish	All low, R highest	Fixer
Color Developer	Light greenish yellow	All low, G lower, B highest	Bleach
Fixer	Reddish	R low	Bleach

2. What could cause the red control points to be high?

2-15. Improving Product Quality

The machine processing personnel and the quality assurance personnel must work in close harmony to produce the best possible photographic product. Without the efforts of both, the ultimate goal could never be obtained. The skilled operator must know the idiosyncrasies of his or her processor. Likewise, one of the quality assurance personnel must know the characteristics of the material being used, and how to change processing factors to obtain the desired end product. However, once these decisions are made, it is the operator whose application of these decisions produce the needed product.

426. Identify those processor functions that can be changed to improve product quality.

Manipulation of Processing Variables. What processing variable can be altered to obtain changes in the quality of the product? Actually, very few. Let's take a look at some of them at this time.

The quality of black-and-white products is usually measured in terms of density and contrast. Density is usually thought of as being a product primarily of exposure. If this is true, then density can be changed very little within the laboratory. However, we know from experience that the highlight densities can be greatly influenced by the combination of processing variables used to develop the film. For this reason, a more accurate explanation of density is that exposure determines the density of the shadow area of the scene. If this exposure is sufficient to produce the desired shadow density, then the exposure will be sufficient to create density in the highlight areas. The exact amount of density produced in these highlight areas must then be considered to be the product of development.

From the above information, it can be seen that the only control that the laboratory has in the photographic cycle is contrast. As you know, the processing variables which can be changed to control contrast are developing time, developer temperature, agitation, developer formula, and choice of material. When the optimum degree for each of these factors has been determined, further changes can be made by altering the developer pH.

The quality of color materials is usually measured in terms of density and color balance. You should recall from previous discussions on color that we stated that the contrast of these products is determined by the subject colors themselves, and cannot be greatly altered during processing. In other words, if the product is correctly exposed and processed, the product will contain the ideal contrast for that particular scene.

The variable which influences the final density and color balance of these products can be restricted to solution temperature, solution replenishment, contamination, wash water flow rate, and again, pH.

Exercises (426):

1. What processing variables can be changed to improve black-and-white photographic quality?

2. What processing variables can be changed to improve color photographic quality?

427. Determine the result of processor defects on photographic quality.

Influence of Processing Variables. As previously discussed, an increase in developing time, developer temperature, agitation, and developer pH increases the contrast of black-and-white materials. A decrease in any or all of these variables results in a decrease in material contrast.

Color materials are quite different from black-and-white materials. Experience has shown that, in general, there are four major conditions that may take place, assuming that the solutions have been properly prepared.

Increase in color density. An increase in color density with no significant change in color balance can be the result of the following:

(1) First developer temperature too low.
(2) Prehardner temperature too high.
(3) First developer replenishment too low.
(4) Shelf life of the first developer replenisher has been exceeded.

The method for correcting the first three variables should be evident. However, to correct for the exceeded shelf life of the first developer replenisher, in addition to replacing it with fresh replenisher, a quantity of fresh replenisher should be added directly to the first developer solution being used.

Decrease in color density. A decrease in color density with no significant change in color balance can be caused by the following: (1) First developer temperature too high.
(2) Prehardner temperature too low.
(3) First developer replenishment rate too high.
(4) Prehardener precipitation. The temperature of the prehardener in the machine or storage tank may have dropped below 68°F, causing precipitation of the sodium sulfate present in the solution.
(5) Prehardner replenishment rate too low.
(6) First stop replenishment rate too low.

The correction for improper solution temperatures and replenishment rates is again evident. When the problem is determined to be related to the prehardener, the solution in the processor must be dumped and fresh solution used. In addition to adjusting the replenishment rate of the first stop bath, if this is determined to be the cause of decreased density, the pH of the solution in the tank must be adjusted to bring it back to normal.

Changes in color balance with no change in density. Changes of this type can be a result of a change in the pH of the color developer and emulsion stain.

a. Change in pH of color developer:

(1) Magenta—blue color balance. High green—low blue readings. This is normally caused by a low pH of the color developer. Add 1 ml of 7.0N sodium hydroxide per liter of developer in the machine. This addition should raise the pH of the color developer 0.1 units and decrease the color spread by 0.10 density units. Some possible causes for low pH are color developer replenishment rate too low, lack of floating cover or an ineffective one on the color developer replenisher tank, or excessive shelf life of the color developer replenisher.

(2) Green—yellow color balance. High blue—low green readings. This is caused by a high pH of the color developer. Add 1 ml of 7.0N sulfuric acid per liter of developer. This addition decreases the color spread of 0.10 density units and lowers the pH by 0.1 unit. The most probable cause of high pH is too high a color developer replenisher rate.

b. Stain. Stain is an overall coloration of the film. It is first detected in the D-min area of the sensitometric strip:

(1) Magenta—red stain (high green reading in step 1). This is most often caused by carryover of color developer into the bleach. However, it can also be caused by underreplenishment or exhaustion of the second stop bath or by an inadequate wash water flow rate of the second wash.

(2) Yellow stain (high blue reading in step 1). Caused by incomplete fixing.

Change in color balance with significant change in density. Contamination of processing solutions with other processing solutions can result in this effect. There are too many possible effects to list them all here. However, they may be obtained from the manufacturer of the color products being used if you need them in your laboratory.

Exercises (427):

1. If black-and-white developer is overreplenished, what is the effect on negative density range?

2. If the color prehardener temperature is too high, what effect does the increase temperature have on color density?

3. What is the effect on color materials if the color developer is overreplenished?

428. Given hypothetical quality assurance data, determine what changes should be made to bring the processor into standards.

Interpretation of Quality Assurance Data. The decisions made by quality assurance personnel are based on (1) the required end product, and (2) the photographic characteristics possible with the process at that time.

The use of control charts is a valuable tool in making these decisions. As an example, a downward trend in gamma for black-and-white products may indicate one of several things. The quality assurance person must first determine what is causing the trend, and then decide what corrective measures are necessary to correct it. While the color process is much more complicated than the black-and-white, the manipulation of processing factors is much more restricted. The person's job here is only a matter of maintaining correct density and color balance once these are established.

It might be good at this point to review some of the information previously discussed that can be related to the interpretation of quality assurance data. One of the prime factors in photographic solution control is its pH. Even when pH measurements of the solutions being used are not known, the behavior of the control chart data for other factors can indicate to the quality assurance personnel the state of the solutions.

Overreplenishment of any developer solution, either black-and-white or color, increases the pH of this solution. When the pH is increased activity is also increased. Increased activity results in increased density and gamma in black-and-white materials. Raising the pH of a black-and-white fixer solution results in decreased fixing capability. In color solutions, the effect of pH change depends on the individual process solutions. Instead of repeating these changes verbatim, refer to the text for Objective 427. The opposite of what has been stated about increasing solution pH holds true when the pH is decreased. As an example, decreasing the pH of black-and-white developer results in decreased gamma and density.

Naturally, pH values which are out of the control limits on the control chart can not be tolerated. For most black-and-white developers, this condition can be corrected by adding additional replenisher when the tank solution pH is low, and processing flash film without replenishment when the pH is high. As discussed in Objective 427, the pH of color developer is usually adjusted through the use of 7.0N sodium hydroxide and 7.0N sulfuric acid.

Overreplenishment or underreplenishment of black-and-white solutions is indicated on control charts by trends being established for pH, gamma, or maximum density.

Exercises (428):

Determine what changes should be made in the process for each of the following situations.

1. The pH of the black-and-white developer is too low.

2. Control charts for the color process indicate trends being established in increasing green densities and decreasing blue densities.

3. The color process control chart indicated that the blue density is too high.

CHAPTER 3

Continuous Imagery Processing Systems

IN THIS CHAPTER you are going to study processing machines and the techniques essential for the production of different photographic products. The success of continuous production depends on the accurate, consistent processing of the exposed film. This is why you must learn as much as you can about the systems and techniques of continuous imagery production.

3-1. Original Negative Processing

There are mainly three continuous imagery processing systems in use today. The first traces its origin to the beginning of imagery production and involves development by immersing the film in the processing solutions. The second is a refinement of the immersion system in which the solutions are sprayed onto the film. The third involves development by applying a thin layer of viscous developer to the emulsion side of the film.

429. State the advantages and disadvantages of using spray-type processing systems for original negative production.

The Spray System. As you know, increasing agitation during processing speeds up the function considerably. Agitation serves one major purpose; it provides a continuous supply of fresh solution to the film surface. We can reason that as the rate that fresh developer applied to the film surface increases, the rate of development becomes faster. Spraying (impinging) the developer directly upon the emulsion has a tendency to force the solution into the emulsion, which speeds up the process. Moreover, spraying insures that there is a constant fresh supply of solution present, which also speeds development. Because the high impingement spray method is so efficient, it is also used in fixing and washing.

In general, a spray processor consists of empty tanks through which the film passes. As film moves through the tanks, solution is sprayed against the emulsion. Spray heads are often mounted on both sides of the film so that spray pressures are equalized and film will not be pushed to one side.

There are two main spray processing configurations. One sprays fresh solution which is used once and then drained away. The other employs a sump in which the solutions accumulate to be pumped through the spray system onto the film and back to the sump. Both systems are in common use, and we will discuss the advantages and disadvantages of each.

The cost of spray processors is high because of the electrical, mechanical, and hydraulic complexities. There is one other major problem. You know that when a developer solution is exposed to air, it oxidizes rapidly. During spray processing, the oxidization is speeded up, since the exposure of developer to air is accelerated. This is why some systems use the developer only once, after which it is drained to waste. In systems where the solution is used again, the machine is equipped with a replenishment system to offset the effects of oxidation. In either system, it helps to use a developer formula with a high preservative content. There are some complex systems in which air within the machine developing tank is evacuated and replaced with nitrogen gas. Nitrogen gas does not support oxidation, and developer used in a nitrogen environment may be recovered and used again and again.

To some extent, high-speed processing is made possible by raising solution temperature. The higher the temperature, the more active the solution becomes. There is, of course, a limit to temperature increase. If you go above a certain point, emulsion damage may occur. In the machine we are discussing, 80°F. is considered an optimum temperature. Raising solution temperature shortens processing time, and you must increase the feet-per-minute speed accordingly. Obviously the production rate increases in proportion to the reduction in processing time.

Operating at high temperature is not the only means of shortening total processing time. Although total immersion systems at 80°F. have a higher production rate than total immersion systems at 68°F., a further increase in production can be brought about by the employment of a spray system. The high-temperature liquids (developer, fixer, and wash water) are applied to the film surface in a high-intensity spray. Heated air is similarly impinged on the film for squeegee action and for drying.

The design of a spray impingement system is quite important, since uniform processing of all types of black-and-white film over the full range of processing speeds and temperatures must be obtained.

Exercises (429):

1. What is the advantages of the spray-type processing system?

2. What are the disadvantages of the spray-type processing system?

430. Describe how film is prepared and assembled for processing and how solutions are verified prior to and during processing.

Original Negative Processing. In any positive-negative photographic process, producing the original negative is perhaps the most important stage. This is especially true in continuous imagery processing, since so many steps must follow the first one before a finished print is finally released, and every generation of a production depends upon having a good negative to start with. You can readily see that nothing may be left to chance. You must not only know what takes place during development, but you should record every step of the process. The number of records kept is governed by the complexity of your operation. In a small section doing a limited amount of work, not many records are needed, but in a large facility performing a wide variety of tasks and producing large volumes of films, a great many records must be kept. But regardless of the size of your operation, you must keep records, and you must keep them accurately. Let's trace an original negative through some of the paths it could take in a production facility.

Assembly. In a large installation, the unprocessed film may come in various lengths and security classifications and on any of the emulsions handled by your laboratory. Short lengths may be sorted according to size, emulsion type, and classification, then logged and assembled into large rolls for processing.

Processing. If you are assigned to operate a processing machine, you will perform the following tasks:

a. a. Upon receiving the film from makeup, check the magazines against the work orders, noting any special processing instructions, and then consign the films to appropriate machines for processing.

b. Before starting a processing run-on product, certify the machine. Communicate (using the intercom) with the solutions control section and verify the solutions contained in the machine and the replenishment rate for the film to be processed. Then run a scratch test. Cut off the scratch test and send it to the inspection section. Upon receipt of a satisfactory scratch-test report, prepare to run product.

c. Notify solution control that processing is about to begin, and once more, verify the solutions and replenishment rate. Start the machine and process the film.

d. While the film is being processed, watch the machine closely to insure that the machine speed and temperature do not fluctuate; that the film passes smoothly over the rollers; that the replenishment rate is constant; that the fixing and washing stages are performing properly; and that the drying is correct. Be alert to make corrections if any malfunction occurs.

e. As each job comes off of the machine, check the film against the work orders and after making appropriate entries on the machine processing production log, send the film on to the inspection section.

f. Continue processing until all work is completed. If more than one machine is being operated, be particularly careful to see that the proper film is developed in the proper machine.

Inspection of processed film. After processing, the film is delivered to the quality control section for evaluation. Should you be assigned to this section, you might perform any of the following tasks:

a. Check the incoming film to verify that the numbers on the film coincide with the numbers on the work orders.

b. Inspect each roll of film for defects and record the kind and number of defects present.

Editing. All processed original film must be edited. During the editing step, all unwanted material is removed, and head and tail leader or frisket strips are attached. A more detailed discussion of this task is given in Volume 2 of this CDC.

Exercises [illegible]: 430

1. How should short rolls of film be prepared for processing?

2. How should solutions be verified during original negative processing?

3-2. The Immersion System

In most imagery production facilities, there is a great need to make duplicates of the original negative. If a large number of prints from a particular original negative are needed, you would make a duplicate positive, called a master positive (in the motion picture industry, *master positives* are sometimes called *finegrains or lavenders)* and perhaps several duplicate negatives. Duplicate negative are commonly called *dupe negatives* or simply *dupes*.

The type processing system that is more common to duplicating material processing is the immersion system.

431. Cite the advantages and disadvantages of using immersion-type processing systems for reproducing original negatives.

Advantages and Disadvantages of the Immersion System. Immersion processing has many advantages. It is a system refined through many years of development, and it lends itself well to production work where chemical controls are rigid. Such factors as temperature, replenishment, agitation, development times, etc., must be carefully controlled. When used for ground-support application, liquid-immersion processes constitute reliable high capacity, economical processes that can accommodate a large variety of photographic materials, and a wide range of film input rates. The major disadvantage of this system is that it is somewhat slow—especially when intelligence readout is required in a minimum time.

Exercises (431):

1. What are the advantages of the immersion-type processing system?

2. What is the main disadvantage of the immersion-type processing system?

432. Indicate the probable photographic quality of master positives for hypothetical work situations.

Principles of the Immersion System. In this method, the film is totally immersed in the solution. In machine operation, the time of immersion is dependent upon the geometry of the machine and the speed at which it is set. This method is simply a matter of feeding the film in, through, and out of the various tanks. Once the system parameters are established, the method is stable unless conditions call for an increase or decrease in processing time. A change in time is required when changing the speed of film travel or the amount of film length immersed in the solution.

Film travel is a mechanical factor that produces a chemical effect as a result of more or less agitation. The faster the film travels, the greater the agitation and thus the greater the density—up to a certain maximum agitation point. However, just passing film through the immersion system alone is not satisfactory since speed changes cause density changes. It is better to augment the agitation with some other method so that the maximum agitation point is always available, regardless of machine speed. If this is not done, uneven development can occur, especially during the early stages of development.

In a pure immersion system, motion agitation is usually supplemented by one or more of the following methods:

(1) Large quantities of the solution may be pumped in and out of the tank from a central reservoir. This fluid in motion (recirculation and turbulation) provides for a constantly fresh application of solution to the film.

(2) The above system, rather than just moving a solution in and out of the tank, may include the use of submerged orifices which direct high velocity jets of solution against the emulsion in order to further assure attainment of maximum agitation beyond which further agitation has no effect. This jet application requires the addition of mechanical devices to prevent film from being pushed out of its normal travel path or whipped about due to the jet pressure.

(3) An increase in agitation rate with or without recirculation is often included in immersion-type processors by using the gaseous burst principle. In this system, bursts of nitrogen gas bubbles are released from the bottom of the tank. As the bubbles rise, they turbulate the solution.

As can be seen from the above information, an immersion system incorporating some of the principles of the spray system makes an ideal processing system. This combined system provides for maximum agitation while maintaining a reasonable operating cost. While this combined system is not as rapid as the spray system, it is far speedier than the strictly immersion type.

Exercises (432):

1. If maximum solution agitation is not provided the film during processing, what is the probable result?

2. What are the results if the solution jets on the combined spray/immersion system malfunction during operation?

3-4. Duplicate Negative Production

Duplicate negatives are always made when the original is to be preserved in the archives. The materials used for dupes must have very low granularity and excellent sharpness characteristics. Also, since in duplicating you might want to improve the pictorial quality of the original by expanding or contracting the tonal scale, duplicating materials must have a wide latitude. You can see that a great deal of control is needed, and that the sensitometric procedures established by your quality assurance section must be diligently followed.

433. Given master positive characteristics and a hypothetical printing condition, indicate what photographic results can be expected in the duplicate negative.

The characteristics produced in the duplicate negative are directly related to the characteristics of preceeding generations. If important intelligence information was not recorded in the original negative, or was lost during the production of the master positive, it is impossible to produce it in the dupe negative. Furthermore, each generation of the product from the camera original results in decreased image resolution and acutance.

While these two characteristics become worse from one generation to the next, it is possible to improve the visual appearance of each generation. Visual appearance is dependent upon density and density range. These two factors can be manipulated through sensitometric control to reproduce at any desired levels. As has previously been stated, exposure controls minimum negative density. If this statement is true for camera exposure, then it is also true for printer exposure. In other words, the printer exposure must be such that a minimum acceptable density in the dupe is obtained. Once this exposure is sensitometrically determined, the density range is then the sole product of the process gamma. The higher the process gamma, the greater the density range.

As can be seen from the above information, the production of duplicate negatives is not a simple task. Characteristics produced in this generation is a cascading of the characteristics of preceding generations. While many of these characteristics become worse with each generation, the visual appearance can be improved through sensitometric control.

To help simplify this task, many laboratories are starting to use a direct-reversal duplicating film that is available on the film market today. This film is designed for one-step duplication of negatives or positives with conventional three-stage processing.

The emulsion develops to high density without exposure; with increasing exposure, the density decreases. Therefore, light passing through clear areas of an original will produce low densities, and light absorbed in the high-density areas of the original will result in high densities in the duplicating film. When printed in the usual manner, the result is a "duplicate" of the original.

Exercises (433):

Determine what photographic effect will probably result from the following situations.

1. The effect overexposure will have on the minimum-density areas of the duplicate negative.

2. The influence on the duplicate negative density range when it is overdeveloped.

3. Underexposure and underdevelopment will have what effect on the:

   a. minimum-density areas of the duplicate?

   b. density range of the duplicate?

3-5. Duplicate Positive Production

Many times, duplicate positives must be made from selected aerial reconnaissance duplicate negatives. These are most often used for staff and pilot briefings and for electronic transmission. However, special interpretation might also dictate the need for such products.

434. From listed duplicate positive undesirable characteristics, determine what corrective action could have prevented such conditions.

As with all duplicates, the use of duplicate positive determines the final product characteristics. It is unrealistic to even consider making positives which contain identical densities and density range when one is to be viewed by transmitted light and another viewed by reflected light. If the impression made by two positives, one viewed on a viewing table while the other is projected on a screen, is to be the same, the positive that is projected must have a greater density range. This can be explained by reviewing the effects of atmospheric haze on the camera produced image.

In aerial reconnaissance, low-altitude photography is affected very little by a haze or atmospheric pollutants. But as the altitude of the camera platform increases, more and more blue and ultraviolet light rays are reflected from airborne particles of dust, smoke, rain droplets, etc. This reflected light passes through the lens during exposure. Since it was not reflected from the subject, it enters the camera in a random manner and creates an overall weak exposure. From experience you know that the most dramatic effect of this type exposure is evident in the low-exposure areas of the negative. This condition reduces the density range of the negative unless corrective measures are taken during processing.

The same principle holds true for projected images. Even when viewed in a room completely void of outside light, enough light escapes from the projector being used to produce the effects similar to the effects of atmospheric haze in camera film. For this reason, positives for projected viewing must contain a higher density range than the positive that is to be viewed by transmitted light.

Applying the previously learned principles of density and density-difference manipulation, a skilled operator can produce, within reason, the required characteristics in any duplicate product. To do so, however, requires that the operator know two things other than his or her process capabilities. These are (1) the input into the duplicating system (in terms of maximum density and density range) and (2) the required duplicate product characteristics (in terms of minimum density and density range).

Assume that a reproduced negative has a density range of 1.50 and is to be duplicated to both a viewing positive and a projection positive. The established standards might dictate that viewing positives have a density range of 1.25, while projection positives have a density range of 1.85. In this example, the density range must be compressed during duplication to yield a satisfactory viewing positive, and it must be expanded during duplication to yield a satisfactory projection positive. These changes can be accomplished through the control of process gamma. Since a process gamma of 1.00 is assumed to reproduce identical density ranges (input = output), it is only logical that a process gamma less than 1.00 will compress the density range, and a process gamma greater than 1.00 will expand the density range. To determine the exact process gammas needed is simply a matter of division. That is,

$$\frac{\text{output}}{\text{input}} = \gamma$$

In our examples, the computations for determining the required gamma for the viewing positive would be

$$\frac{1.25}{1.50} = 0.83$$

Likewise, the computations for determining the required gamma for the projection positive would be

$$\frac{1.85}{1.50} = 1.23$$

Therefore, the viewing positive must be processed to a gamma of 0.83, and the projection positive must be processed to a gamma of 1.23 if the desired density range is to be obtained. Gammas higher than those computed will result in an excessive density range. Gammas lower than those computed will result in low, and possibly unusable, density ranges.

Once the gammas are determined, the tone control charts can be consulted for the required exposure. It must be remembered that material sensitivity is influenced by process gamma, and increases as gamma increases. This is to say that film processed to a gamma of 1.23 will contain more density than the same film processed to a gamma of 0.83 when both are exposed identically. The product results of these conditions would be low minimum densities when underdeveloped, and high minimum and base fog densities when overdeveloped, even though the exposures were correct for the computed gammas.

These principles hold true for any situation. Just as there are ideal densities and density ranges for reflected viewing, there are also ideal density range and densities for every situation encountered. Only through the application of sensitometric control can these characteristics be obtained.

Exercises (434):

From the following list of unsatisfactory duplicate positive conditions, indicate what process variable could have been changed to prevent such conditions.

1. Viewing positive with too high a density range.

2. Projection positive with too low a density range.

3. A positive with too much contrast and a high base fog density.

3-6. Reversal Materials

The processing of color film is a very critical process. Since precision machines are used, the operation is not difficult but it is critical. Each step of the process must be within specified quality control tolerances. Maintenance of many of these tolerances is a direct result of how you set up and operate the machine.

In most instances, the operational tolerances you work with are provided by the quality assurance section of your lab. In general, quality assurance establishes a set of conditions for each machine and each product so that there is a uniformity of product. This is ideal. However, this is not always possible, mainly because of emulsion-to-emulsion variations. Fortunately, such variations can be corrected in printing. But, such corrections are effective only if the variables in processing are held to a minimum. Therefore, we say that while machine operation is not difficult, proper procedures are critical.

435. Given conditions that might be encountered during reversal processing, indicate what corrective action might be required.

Reversal. Reversal processing occurs in five major steps. These are:

(1) First development.
(2) Reexposure.
(3) Color developer.
(4) Bleach.
(5) Fix.

The sequence in which the developers are used is important in the reversal color process. Both developers will reduce the exposed silver halides to metallic silver. However, only the color developer is capable of forming color dyes within the emulsion. If color reversal material is subjected to the color developer first, it will produce a metallic silver negative image (instead of a metallic silver positive image), as well as a color dye image. Since the dye images are produced in conjuction with the formation of a metallic silver image, this subjection of the exposed material to the color developer first would produce quite an unusual visual effect. Consider the following example. A yellow daffodil is photographed on a blue background and the film is subjected to the color developer first. Here, we are dealing with three basic colors. These are yellow (flower), blue (background), and green (flower stem). During exposure, the yellow would expose the red and green sensitive layers of the film. Likewise, the green would expose the green sensitive layer, and the blue would expose the blue sensitive layer. During processing, the formation of silver in the blue sensitive layer produces yellow dye, in the green sensitive layer it produces magenta dye, and in the red sensitive layer it produces cyan dye. Therefore, our transparency would be of a blue daffodil (yellow exposing light results in magenta and cyan dyes being formed during processing, which yields the color blue when viewed by transmitted light), on a yellow background (blue exposing light result in yellow dye being formed during processing), with magenta foliage (green exposing

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light results in magenta dye being formed during processing). It can be seen that the colors produced in this situation are the opposites of those in the scene, and can, in reality, be called a negative image. The quality of this product will not be good, however, due to the amount of exposure and the activity of the color developing solution.

The processing steps for a specific incorporated coupler reversal system we shall cover here are those pertaining to Eastman Ektachrome Commercial Motion Picture Film. The first four steps must take place in the dark. The room must be dark or the magazine and the machine tanks must be lighttight. Subsequent steps of processing can take place under room illumination. While not a part of the actual processing the loading tank of the machine must also be lighttight. These steps for motion picture processing are:

a. Backing removal—the antihalation backing is removed by a scrubbing action and a spray of water. This action prevents the first developer from becoming contaminated and discolored from the dye forming the antihalation backing.

b. First developer—a black-and-white silver image is produced in each of the three film emulsion layers.

c. Wash—developer solution is washed from the film.

d. First hardener—this solution hardens the emulsion to prevent excessive swelling and damage in subsequent processing steps.

e. Wash and reexposure—this wash removes the hardening solution from the film and at the same time, the remaining silver halides in all three emulsion layers are exposed to light.

f. Color developer—this develops the areas exposed in the previous step and produces positive images of silver and dye.

g. Wash—this wash removes the color developer from the film.

h. Second hardener—this hardens the emulsion to prevent excessive swelling caused by the bleach.

i. Wash-hardening solution is washed from the film.

j. Bleach—the bleach removes the yellow filter layer between the top two emulsions and converts all silver to a silver complex which is soluble in a fixing bath.

k. Wash—bleach solution is washed from the film.

l. Fixing bath—silver compounds are fixed out.

m. Wash—fixing solution is washed from the film.

n. Stabilizer—this hardens the emulsion and stabilizes the dye images.

o. Drying.

Processor Mechanical Control. The size, shape, and operating mode of processing machines vary greatly and each processor-process combination is unique. However, their basic function is the same, and that is to transport the film through the processing solution to permit an appropriate treatment time for the film in each solution bath. The processor must repeatedly accomplish this function within specified control limits. To do this requires that all mechanical factors that affect the chemical constitution of the solutions be under control at all times. The major factors to be considered are:

- Temperature of chemical solutions and wash water.
- Film transport system relative to the time that the film remains in a solution.
- Solution agitation uniformity and recirculation rates.
- Chemical replenishment rates.
- Filtration and flow-rate for wash water.
- Film drier control.

The above factors are quite appropriate for the color "Versamat" processors as well as for motion picture color processor. These processing machines transport the film through the various solution tanks, emulsion side up. The solution tanks of these processors vary in size according to the particular processor. The processing specialist must continuously monitor the mechanical factors affecting the process. For this reason, each of these is discussed individually.

Temperature control. Solution and wash water temperature represents one of the most critical areas of control for a color processing system. The final dye density and color balance varies significantly as a function of temperature.

A change in the first developer temperature of ±1° to 2°F. can produce a density difference in a transparency of sufficient magnitude to exceed most process control limits. Excessive temperature can also cause physical damage to the emulsion as well as to the image structure and stability.

The temperature of the wash water, along with its flow-rate, affects the rate of development by product removal from the film's surface. Therefore, the recommendations of having hot and cold water for the processor, as required by the appropriate technical order, should be strictly adhered to. In some cases where the local water conditions cannot meet these recommendations, additional heaters or chillers along with booster pumps must be employed in the water lines.

Most color processors are equipped with temperature gauges which can be easily read and adjusted within their intended limits. To insure that the correct temperatures of the various solutions are maintained, they must be checked periodically. Use a good thermometer such as the Kodak Process Thermometer, Type 2. If necessary, adjust the temperatures to the recommended value.

Film transport control. Rigid control over the film transport system is important to color film processing because of its impact on photographic quality. The treatment time is controlled by the film drive system that transports the film through the various solutions. This speed factor is calibrated to the specific film-developer-temperature combination given for the particular type of film being processed.

Mechanical control checks of the entire film transport system should be made frequently before and between film processing operations. Any nonstandard conditions must be noted and corrected immediately before mission film is processed. Normally, the film transport speed should be tested and adjusted to the established standards during the daily startups.

Solution agitation and recirculation control. An important mechanical feature of automatic film processors is the method and degree of solution agitation, filtration, and recirculation. Mechanically, these functions generally comprise an integrated system since they all contribute to the agitation of processing solutions and hence affect the density, contrast, and color balance of the final product.

Also, when there is insufficient agitation or recirculation, uneven development takes place, causing irregular streaks and mottle to appear in the imagery.

In addition, both the processing solutions and wash waters usually contain some insoluble material in the form of solids and tars. Some of these salts can be redissolved, while other salts along with the tars are usually insoluble. If these materials are not removed, they will adhere to the film being processed as well as the surfaces of the processor. Therefore, filtration systems are required in replenisher lines, recirculation systems, and wash water lines.

Although, during the permission certification, tests are run to detect streaks, mottling, and the other effects, there is very little one can do during the processing of mission material other than:

- Evaluate the developed product with respect to image uniformity.
- Check processor development uniformity between mission rolls.
- Monitor the pressure differential across the filters to insure that the filters have not become clogged.
- Check chemical solution pressures at the processor.

During processing, the agitation the film receives is controlled by two factors. These factors are the speed of the transport system and the recirculation of the solutions. In most processors the recirculation system includes the filtration, replenishment, and temperature control of the processing solutions. This arrangement affords a means of maintaining a quality and uniform process.

Since most processors employ flexible recirculation hoses within their systems, the flow of the solutions can be easily determined by pinching the inlet hose together at the machine. This is normally accomplished at each startup to prevent a clogged hose or filter from burning up the solution heater. If there is no flow, check the tanks for the formation of crystal. If there are none, check the filter or the recirculation pump. The recirculation pump may be checked by simply laying the hand on the outside of the pump housing.

To insure proper filtration of the wash water, inline filters are installed before the water reaches the mixing valve. Also, it is highly recommended that pressure gauges be installed on both sides of each filter. The gauges serve two purposes. These are: (1) to monitor the water pressure that is reaching the mixing valve and (2) to monitor the pressure differential of the two gauges to denote the condition of the filter itself. Normally, a 10-pound pressure difference between these two gauges indicates a need for a filter change.

Replenisher control. As film is processed, the individual chemical components of the processing solutions are consumed at varying rates. Good quality assurance practices require that the chemical composition of these solutions be maintained at their optimum levels. An accurate and reliable replenishment system that will maintain the chemical composition at uniform values is therefore required.

Most of the color processors incorporate an automatic replenishment system that has a flowmeter for each solution. The flowmeter is manually set to obtain the specific replenishment rates. Also, each solution is equipped with its own replenisher pump to draw the solution from the respective storage tanks.

The scale of these flowmeters is graduated in arbitrary units. Since the specific gravity of each solution will vary, individual flow rates must be established. These flow rates may be determined either with water or the solution itself. It should be remembered that if the flowmeters are calibrated with water, the specific gravity factor for the particular solution must be taken into consideration. To simplify and improve accuracy, it is recommended that the flow rates be determined with the actual replenisher solutions. However, extra handling precautions must be exercised with this procedure.

The computation of the replenishment rates is based on the square footage of film processed. Therefore, these flow rates should be calibrated for all sizes of film processed on that machine. With Kodak films, these replenishment rates are computed and can be found on the data release sheet for the particular film and size being processed.

Once the flowmeters are calibrated, they are manually adjusted for the desired flow rates. However, during operational periods the flowmeters must be frequently checked to insure that the specified replenishment rates are being maintained.

Film dryer control. Rigid control of the dryer operation is required to insure that mechanical components affecting temperature, humidity, speed, and tracking do not have adverse impacts on the physical quality of the film. Proper control requires frequent checks to insure that the temperature and humidity are kept within specified tolerances, and that the film transport system is tracking properly and operating at proper speeds. In addition, a continuous inspection should be made of the processed film leaving the processor. Insufficient drying is indicated by soft and stick film emulsion. Overdrying is evidenced by excessive curling, brittleness, and sometimes emulsion blisters. A good criterion to determine proper drying is that the film should be dry without tackiness when it is about two-thirds of the way through the drier cabinet.

As previously mentioned, most of the control tolerances for the processing of various Ektachrome films are given on individual data release information sheets supplied by Eastman Kodak. Also, some of the control tolerances may be found in the technical manual which applies to the appropriate processor. Eastman Kodak is constantly updating its information data to conform to the company's latest films and processing specifications. Therefore, it is a good practice to keep in touch with the manufacturer for any changes or problems encountered.

Exercises (435):

1. During motion picture film processing you notice that the first developer is extremely dark. What could cause this discoloration?

2. Color film was introduced to the color developer first, and then to the subsequent processing steps in order. What would be the probable results?

3. An uncalibrated Kodak Process Thermometer is used to check and adjust the solution temperature gauges on a color processor. Film that is then processed on this machine contains excession density. What processing factor could produce this increased density and how can it be corrected?

4. Development mottle is noted on processed color film. What could cause this and how can this condition be corrected?

3-7. Threading the Processor

Now that we have briefly discussed the three general ypes of processing systems and the types of material that you may be responsible for processing, it is time we turned our attention to other subjects related to processing. The first of these will be leadering the processor.

436. From given film widths, determine what type threading should be used.

Threading the Processor. Some processors are threaded with leader prior to operation and then deleadered at the end of the operation. This is necessary because the leader touching the transport rollers, while both are stationary, will result in a flat spot being formed on each roller. Such a processor is the "Fultron."

Still other processors are threaded with leader and are never purposely deleadered unless for maintenance reasons. An example of this type processor is the "Labmaster."

When a processor uses leader material to pull the film through the processor, only two methods of leader threading are possible. These are the loop-type threading and the over-under type threading.

Loop-type threading is used for narrow film processing. These processors are constructed so that each roller assembly contains two or more transport rollers, with one roller more on the top assembly than on the bottom. An example of this can be seen in figure 3-1. Refer to this figure while reading the following paragraph.

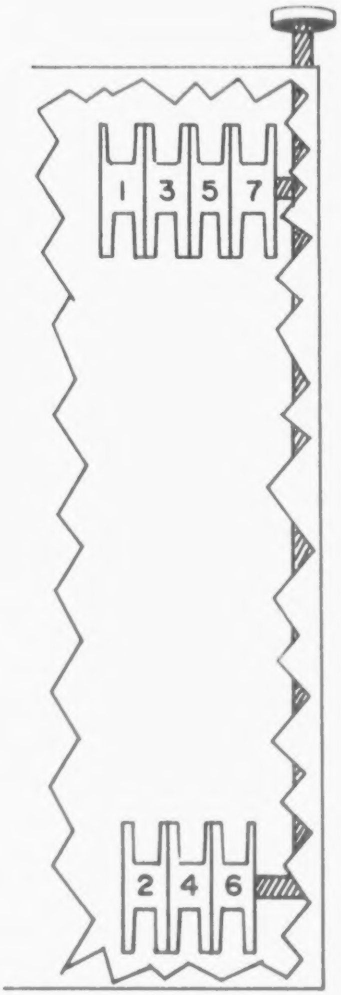

Figure 3-1. Roller assembly.

This type system gets the name "loop-type" because the leader forms actual loops when it is threaded. In the illustration, visualize leader entering the assembly from the tank directly behind the assembly shown. The leader will be threaded so that it passes on top of roller number 1. Then, it goes down and underneath roller number 2, up to roller number 3 where it crosses the roller from the rear, as pictured. This procedure is continued until roller number 7 is reached. This roller is used to guide the leader to the top of the next roller assembly. One advantage of this threading method is that the material emulsion never touches the transport rollers.

The over-under threading system is used for wide film processors. In this system the leader passes on top of the top roller and underneath the bottom roller. The material emulsion does come into contact with the bottom rollers in this threading method.

There is nothing dictating which type threading is designed into the processor other than processor size. It would be unrealistic to design a loop-type system which is to be used to process 9½-inch film, because the width of the processor would be prohibitive. Also, an over-under system designed for narrow film would not likely require an extremely long processor with solution tanks holding hundreds of gallons of solutions. Narrow films, those which are processed by the loop-type system, generally include all

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widths up to 70 mm. Films are usually classified as wide when they require the over-under threading system. This usually includes all film widths in excess of 70 mm. The 70-mm film can be classified as either wide or narrow, according to use, and can be processed using either of the threading systems. As an example, 70-mm motion picture film would be considered wide to the motion picture laboratory specialist, and if processed on a processor designed for motion picture material, would probably be processed using the over-under threading system. However, most conventional aerial film processors designed to handle only 70-mm film would probably use the loop-type threading, and the material would generally be classified as a narrow film.

Exercises (436):

Following are maximum film widths that given processors are designed to handle. Determine what type threading system would be best for each.

1. 9.5 inches.
2. 6.6 inches.
3. 5 inches.
4. 70 mm.
5. 35 mm.
6. 16 mm.
7. 8 mm.

3-8. Splicing During Operation

Cutting and splicing are used extensively with aerial rollfilm and other long lengths of film and paper processing. However, splicing during operation is possible only on machines that are of the leader-type threading and that have load accumulator sections.

437. List the factors that must be considered when determining the length of time an operator has to make a running splice.

Factors Governing Running Splices. Splicing is a relatively simple operation but the splice must be durable in both the wet and the dry state and capable of withstanding movement through various machines. Additionally, the splice should not be appreciably thicker than the film itself.

It takes practice to be able to make running splices successfully. The maximum allowable time for making running splices depends on the footage of material in the accumulator section and the transport speed. Splicing, as related to imagery production processing, must be accomplished within the given time limit. This is because the processor draws from the film in the accumulator section to provide a continuous supply of film for the solution while the splice is being made. If too much time is used to make the splice, all the film in the accumulator section is used and the transport for most processors is automatically cut off.

Exercises (437):

1. What two factors must be considered when determining the length of time the operator has to make a running splice?

438. Given hypothetical amounts of film in the accumulator section and the processor operating speeds, calculate the maximum time that an operator has to make running film splices.

Determining Maximum Splicing Time. As previously indicated, the time allowed for making running splices depends on the footage in the accumulator section and the transport speed. Naturally, for any given processor, the faster the transport speed the less time available for making the splice. However, during the processor planning phase, the maximum transport speed that will be possible for the processor is considered before the accumulator section is designed. In other words, a certain manufacturer might base his or her design on the time it takes a skilled operator to make a splice. If this time is 15 seconds and if the maximum transport speed is to be 100 fpm, then the accumulator section would be designed to hold 25 feet of film (100) fpm × 0.25 minute = 25 feet).

Before attempting to make a running splice, the operator must know the maximum splicing time. This knowledge and proper splicing techniques can preclude many embarrassing situations.

Exercises (438):

Determine the maximum splicing time in seconds that is available for the following conditions:

	Accumulator Footage	*Transport Speed*
1.	20	20 fpm
2.	30	50 fpm
3.	15	40 fpm
4.	18	35 fpm
5.	25	75 fpm

3-9. Emergency Operating Instructions for Film Breaks

As the supervisor of a photographic section, your primary day-to-day task is to conduct a smoothly operating production plant. To do this, you should draw up a set of operating instructions to cover every phase of your operation. An example of these documents is the office operating instructions (OOIs). But whatever they are called, they outline the duties of all of the personnel working in your facility, describe the procedures to be followed for every task, and set the standards of quality for the finished products.

This, and the following two sections are concerned with information related to the processing of original photographic material that should be covered by OOIs. Now, let's look at the instructions that should be in the OOIs for film breaks during processing.

439. Name the items of informtion that should be included in an OOI, and list the wet splicing methods that should be included in the OOI as being best suited for film breaks.

Office Operating Instructions. In preparing an OOI for any operation or procedure, you should remember that the format for an OOI is never rigid. It should be remembered that the format for an OI is never rigid. It should be uniform throughout your organization, but it need not be the same as that used by other organizations. Regardless of the particular format, your OOI should include the following:

- Heading, including OOI number and date.
- Subject.
- Purpose.
- Responsibility.
- Abstract (optional, desirable if the procedure is lengthy).
- References (if applicable).
- Procedure (step-by-step).
- Signature element (including approval or interested official).

All of these items are more-or-less self-explanatory. However, let's investigate the information that should be considered when writing the procedures part of the OOI that will cover film breaks.

The first consideration, of course, is the type processor being used. Generally speaking, there are three types that must be considered. These are narrow film, leader-type threading; wide film, leader-type threading; and wide film, leaderless type.

In most cases, the system that uses leader to pull the film through the solutions incorporates dip rods or elevator assemblies. This allows for the processor to be stopped, and the elevators raised until the ends of the film can be overlapped at the break and spliced.

For narrow-width film, it would probably be best to splice the two ends together with stainless steel staples, since expediency is necessary to salvage as much of the film as possible. This should be accomplished by overlapping the trailing end with the leading end and placing at least five staples in the overlapped section. This system is recommended for film breaks on the colormaster motion picture processing machine.

For wide-film processing, correcting for a break is a little more difficult. In the leaderless systems where leader material is used only for guiding the leading edge of the film through the processor, a tape (Mylar) splice can be made. However, you must remember that the leader material and both sides of the film must be as dry as possible, and the leading edge of the film must be trimmed so that it is square. Furthermore, the splicing tape must adhere to both the film material and the leader material. Staples should never be used for correcting wide-film breaks because the full width of the film comes in contact with the processor rollers. This would probably cause damage to each roller the staples touch.

Wide film, leader-type systems are the most difficult breaks. For some processing systems, it is best to cut the film in the accumulation tank and hand process this section of film. The processor can then be rethreaded and processing continued. This system is used on the Fultron processor. For other systems, it might be advisable to raise the elevator assemblies until enough film is available to overlap the break approximately 6 inches. The film is then wiped dry and Mylar tape encircled both layers of film to cover both the leading and trailing edges. This is the most dangerous method since the tap will not completely adhere to the still-damp film and another separation might occur. Again, the previously stated precautions for using staples apply.

Exercises (439):

1. What items of information should be included in an OOI?

2. Name the wet splicing methods that are best suited for film breaks.

3. What splicing method would you write into an OOI for film breaks that occur on the Colormaster motion picture processing machine?

4. What is the best method of correcting for film breaks that occur on the Fultron processor?

3-10. Emergency Operating Instructions Covering Processor Malfunctions

The objective of operator preventative maintenance and periodic evaluations performed by maintenance personnel is to keep photographic equipment operational. In most cases, this objective is attained. However, the most precision made equipment properly maintained by the most qualified personnel will eventually malfunction. What these malfunctions are and what the operator should do must also be included in the OOIs.

440. Given a list of processor malfunctions that might occur during operation, list the ways that they might be detected.

Once the processor is declared operational and is being used to process sensitized materials, there are not many things that the operator can do to prevent malfunctions. The main concern is getting the product through the processor in such a manner that it is in one continuous strip, free of physical defects and possessing acceptable photographic characteristics. However, some malfunctions necessitate immediate action, whereas the others are identified only for future maintenance actions.

To identify malfunctions while the processor is operating, the operator must use three of his five senses. These are *sight*, *hearing*, and *touch*.

The action that the operator should take when a malfunction is detected by one of these three means depends upon two things. These are how critical the product in the machine is, and the possible damage that could be done to the machine if it is allowed to continue to operate. It is impractical to even consider recommending definite solutions in this CDC. However, these facts must be established at each operational level and strictly adhered to.

Some of the malfunctions that might be detected by one or more of these senses and should be covered in the OOI are as follows:

Sight. Visual evaluation of dip rods or elevator assemblies must be continuous. If these begin to rise, this action indicates that film is not transporting in the processor. This necessitates immediate action. Other areas that must be observed are the takeup, processor control panel, and the immediate processor surroundings for such things as chemical leaks, smoke, etc.

Hearing. Probably the most valuable sense used in determining processor malfunctions is hearing. Well-qualified operators soon become accustomed to the sounds of their processors in much the same manner that they become accustomed to the sounds of their personal cars. Any strange or uncommon sound is immediately noticed. What is more difficult is identifying the cause of such sounds. The causes differ with type of processor, and to some extent, with different processors of the same type. However, unusual squeaks could indicate improperly operating clutches, defective motor bearings, etc.; and bumping sounds could indicate gears not meshing properly.

Since the OOIs are prepared for each type processor, each OOI should be explicit in what each sound could possibly indicate. As previously stated, the actions to be taken by the operator for each peculiar sound must be established at the local operating level.

Touch. The third sense used to determine processor malfunctions is touch. This sense might be used to confirm the suspicions created by the other senses. This includes such things as determining the relative heat of one recirculating pump motor as compared with another, insuring that the film supply is still allowing film to feed into the machine while in total darkness, etc. One precaution should be stated here. Simply being around operating equipment in total darkness is, in itself, dangerous. Placing one's hand in unfamiliar areas of the processor compounds this danger dramatically. Many operators who did not believe this are today minus a part of their fingers, if not entire fingers. Do not overuse this sense of touch in total darkness.

Exercises (440):

List the sense that might be used to determine the following processor malfunctions:

1. Inoperative solution refrigeration unit.

2. Defective replenishment pump.

3. Erratic operation of dip rods or elevator assemblies.

4. Film stoppage.

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3-11. Emergency Operating Instructions for the Prevention of Image Degradation

The last item that should be covered by OOIs that we'll discuss in this CDC is related to the prevention of image degradation or loss during processing. 441. Specify ways of preventing image degradations that might occur during processing.

In each imagery production processing laboratory, three common things that could easily result in image degradation or loss due to improper processor operation should be covered by OOIs. These are incomplete drying, incomplete fixing, and improper film tracking.

Incomplete Drying. This action can result in the total loss of a complete roll of film. Roll film, especially aerial thin base, when not completely dry as it reaches the takeup assembly, will stick to other layers of film. In most cases, once these layers are stuck together, attempting to separate them results in the emulsion of one layer adhering to and being retained by the base of another layer.

We must consider incomplete film-drying from two aspects. The first is how to salvage the film, and the second is how to correct the cause.

Naturally, the most important thing is salvaging the film. In most laboratories, there will be a minimum of two people assigned to each processor, with one of these at the takeup end. It is this person's duty to insure complete film-drying as it exits the processor. If he or she notices that the film is retaining too much moisture (but not considered to be wet), alterations in the process should be made immediately. These could be (1) increasing dry-box temperature or (2) slowing the processor transport speed. Slowing the transport speed, however, increases gamma and densities, but saves the imagery.

A third alternative might be, in the case of short lengths of film, to air-dry the film. This can be done, if you have sufficient laboratory area and personnel, by disconnecting the takeup reel from the processor and spreading the film out in the immediate area. However, this method requires many people to keep the film from touching the floor while it dries.

Once the film has been salvaged, the reason for incomplete drying must be determined before more film is processed. Some possibilities are defective dry-box thermostat, insufficient hardener in the fixer, and improper dry-box humidity control. These items are not covered in this CDC since they are the responsibility of personnel in other AFSCs.

Incomplete Fixing. Incomplete fixing is indicated by a milky appearance in the negatives. If corrected, this condition has very little or no effect on the image quality. However, if not corrected, this milky appearance increases the overall density of the negative and compresses the density range. This results in the need for increased exposure during printing and increased processing gammas for the duplicate.

When this condition exists, two actions can be taken. First, the machine transport speed can be slowed, but this increases gamma and density. Probably a better solution, from the standpoint of photographic characteristics, would be to maintain established processing parameters and then refix, rewash, and redry the film.

This condition is the result of either imbalanced fixer chemical composition, or a fixer formula that is insufficient for the established processing standards. In the first case, increasing the fixer replenishment rate would probably solve the problem. If the fixer formula is wrong, chemical analysis is needed to formulate a new solution or make adjustments to the standard formula.

Machine Tracking. Processors manufactured to handle wide film usually have transport rollers wide enough to allow the film to track off center without endangering the product. However, two major things can result in the film mistracking to the extent that it becomes entangled with the roller drive gears. These are misalignment of transport rollers and improper film magazine setup.

If the transport rollers are not aligned properly, this should show up during the processor setup and mechanical certification steps. Any evidence of misalignment should be pointed out to maintenance personnel and corrected before processing original material.

Correct film magazine setup is the responsibility of the operator (or other personnel responsible for loading the magazines) and the directions for setup should be fully explained in the OOI. While the magazine can be set up to handle any size film up to 9½ inches wide, some processors accept only one size magazine. When these magazines are used to process film narrower than 9½ inches, they should be adjusted for the particular film width. Otherwise, the reels will meander within the magazine and cause the film to track too far off center.

Exercises (441):

1. What should be done if incomplete film drying occurs because of too high dry-box humidity?

2. Describe the procedure best suited for refixing, rewashing, and redrying incompletely fixed film.

3. Explain how the film magazines using film narrower than 9½ inches should be set up to preclude mistracking during processing.

3-12. Monitoring the Process

In concluding this chapter, one final operator task must be discussed. This task is the continual monitoring of the processor during operation. It is not enough to know the processor startup and certification procedures, and the processing requirement for any type materials. When these tasks are learned and executed perfectly, the operator's job has just begun. The operator must insure that the material passes safely through the processor and is deposited at the takeup end in acceptable condition.

442. Specify some of the defects that might appear on film that could have been corrected or prevented by proper processor monitoring.

Monitoring Functions. Once the production run has begun, the monitoring of several processor functions must be accomplished. This continual monitoring is designed to keep a supposedly perfect operating system performing at its optimum capability. Even though the processor is mechanically and chemically certified before the production run is started, changes can occur within the system that would degrade the final product or result in its loss entirely.

Such a change might be the material transport. In systems where the supply magazine is larger than the supply reel (a single 5-inch reel in a magazine capable of handling a 9½-inch reel), and the reel is not held in place by guides, the reel will move from side to side. When this happens, the material will also deviate, possibly causing it to become entangled in the transport roller gears. This may wrinkle or tear the film. Also, in processing systems that contain elevator assemblies, the height of the rods should be watched closely. A rising rod may indicate that a clutch needs to be adjusted or that the transport of the material has stopped because of an improperly made splice. Splices may break when they jam the processor.

The solution replenishment rates and temperatures, as well as the wash water flow rate and temperature, are also important and must be monitored. These must be maintained at the proper levels if optimum results are to be obtained. In most instances, small pressure change within the replenishment system can result in an exaggerated effect on the replenishment rate. When such changes occur, the flowmeter control valve must be adjusted to compensate for these changes. In facilities where sufficient water pressure is not available to handle all work situations, special emphasis should be given to the water supply entering the processor. In such instances, the simple procedure of starting up an additional processor may be sufficient to decrease the amount of water available to the processors already operating. When this happens, the water input must also be adjusted.

Items such as drying temperature and material takeup cannot be ignored. Their monitoring is necessary and adjustments must be made as dictated by each situation. Variations in drying compartments result in drying streaks, overdrying, or underdrying.

Exercises (442):

1. What material defects might result because of improper material transport monitoring?

2. What material defects might result because of improper drying compartment monitoring?

443. Indicate the probable cause of given defects resulting from processor malfunctions.

Defects Produced by Processor Malfunctions. A number of mechanical or physical defects can result from improper processor monitoring. These can generally be classified according to the malfunction which produced them. A skilled operator must be able to inspect the film for such defects as it exits the processor and to immediately isolate the cause of any defect found. As examples, crystallized chemicals on the material can only result from improper washing, and crimped film edges are produced only by undue stress applied on that area of the film. Such defect producing conditions must be isolated and corrected if acceptable products are to be obtained.

Exercises (443):

Determine the probable cause of the following processed material defects resulting from improper processor monitoring.

1. Crystals formed on the film.

2. Torn or crimped edges.

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CHAPTER 4

Postprocessing Tasks

WHEN THE LAST roll of material is off the processor, there is still work to be done. The processor must be shutdown and procedures followed to make certain that it will be ready when needed again.

4-1. Black-and-White Continuous Processor Shutdown

The task of processor shutdown is an important one to the operator as well as to the laboratory. It involves much more than simply turning off switches. Now, let's look at some of the functions required for proper processor shutdown.

444. Given processor shutdown tasks listed in proper sequence, explain why the tasks should be conducted in that sequence.

Processor Operations. When stopping processor operation, you should take steps to prepare the machine for the next mission. On leadered machines, shutdown is initiated by providing sufficient leader to splice onto the trailing end of the film that is being processed. If you automatically thread the processor with leader, the processor is immediately available for the next processing session. Thus, the time-consuming process of manually threading the machine is avoided. An exception to this is when the processor is stripped for cleaning. This requires the removal of all material from the machine and the rethreading of the machine when cleaning has been completed. Replenishment controls should be shutoff as soon as processing solutions are no longer being exhausted.

When leadered machines are not to be deleadered during shutdown, the transport is stopped immediately after the rethreading leader exits the drying compartment. This is to preclude having to use large quantities of leader during the rethreading phase.

Extended periods of inactivity or solution changes requires a complete shutdown. During an extended (complete) shutdown, you should drain the tanks and position all operating switches in their OFF positions. Then wash all of the tanks thoroughly and flush all lines. After they have been drained and cleaned, the tanks should be filled with clear water. *(CAUTION:* Do not overtighten the drain valves. If the machine is idle for long periods with the tanks empty, the valves must be lightly cracked to prevent them from sticking.)

If the processor is to be shutdown for a short period of time, the dryer heater should be turned off, as should the film-transport drive. After the dryer temperature reaches 100° to 110°F., the dryer blower should be turned off. In addition to the above actions the following things should be done:

- When applicable, leave leader threader in the processor and release tension on the last elevator in the wash section.
- Turn off recirculation pumps.
- Shut off water to wash tanks.

The wash water is always turned off after the material transport has been stopped. The primary reason for allowing the material washing to continue until the transport has been stopped is to rid the leader material of all processing chemicals.

For an overnight shutdown, the same procedure used for a temporary shutdown should be followed. In addition, all operating switches should be turned off. The drying compartment blower must remain on as long as sufficient heat remains in the drying compartment to damage the heating elements and leader material. Usually, this is the last shutdown task to be performed. While waiting for the temperature to reach acceptable levels, the operator should perform all other shutdown tasks, including equipment cleaning. The solution temperature control system may be left in operation overnight so that desired solution temperatures can be maintained.

One precaution related to the shutdown of the "Versamat" must be stressed at this point. Processors that contain water conservation units differ from other processors. They require that the wash water be turned off last, even after the dry-box blower.

Exercises (444):

Explain why the following processor shutdown steps for a leadered processor should be accomplished in the sequence listed.

1. Turn off film transport.

2. Turn off wash water.

3. Turn off dryer compartment blower.

4-2. Color Continuous Processor Shutdown

The shutdown steps for color processors are basically the same as those for black-and-white systems. However, as with black-and-white systems, the shutdown procedures for each type color processor differs slightly. In this section, we will discuss those basic steps applicable to all color processors.

445. Given a list of processor shutdown tasks, arrange them in the sequence in which they should be accomplished.

Sequence of Shutdown Tasks. On processors that are threaded with leader, the first step is to again insure that sufficient leader is available and spliced onto the trailing end of the material being processed. If a leaderless-type processor is being shutdown, it must be cleared of all material. When the leadered processors are completely rethreaded with leader, the processor transport system is stopped.

Next, all recirculation pumps, wash water, and the dry-box thermostat are turned off. The replenishment valves should be checked to insure that they are fully closed. In systems that employ the gravity-feed-replenishment method, leaving a replenisher line valve slightly open will allow a continuing replenisher flow even during shutdown periods. When this happens, it causes a change in the chemical balance of solutions. This means that you will have to either adjust or replace those solutions during the next machine startup.

Only after the dry-box temperature has reached 100°–110°F. can the blower be turned off. Since it is suggested that the main drive of the "Versamat" be left on until the dry-box blower is turned off, it too should be turned off at this point.

Except as otherwise specified by the manufacturer, the following sequence of shutdown tasks should be followed for all processors:

(1) Turn off replenisher. If not coupled with the recirculation pumps, the replenisher should be turned off as soon as the last material is processed. Since it would be "guess work" to attempt turning off the replenisher as the film leaves the individual solution tanks, it is best to accomplish this task as soon as the end of the film enters the drying compartment.

(2) Decrease transport speed to 5 fpm. Sudden highspeed transport starts and stops will damage the transport system. Five fpm is ideal because it is slow enough to eliminate most stresses produced during high-speed starts and stops, but it is also fast enough to transport material and operate transport rollers during subsequent startups.

(3) Turn off main drive. This task should be accomplished next to preclude having to use large quantities of leader material.

(4) Turn off dry-box thermostat. This task can actually be accomplished at any point in the shutdown sequence after the main drive has been stopped.

(5) Turn off solution temperature control switches. When not coupled with the solution recirculation pumps, the solution temperature control switches should be turned off before the recirculation pumps. This is to preclude the continuing activation of the solutions' heating and cooling systems while the solutions are not being recirculated.

(6) Turn off solution recirculation switches. Continued recirculation of the solutions will result in a higher degree of solution oxidation.

(7) Insure closing of replenishment valves.

(8) Turn off wash water. The wash water must be turned off as soon as possible to conserve water, but late enough in the shutdown sequence to insure complete washing of the leader material. This is the ideal point for this step.

(9) Turn off dry-box blower. This is accomplished only after the drying compartment has reached a safe temperature.

(10) Turn off main power. This is accomplished after all other tasks have been accomplished. Turning off the main power precludes the accidental activation of processor control switches.

(11) Turn off breaker switches. This is not absolutely required. However, some laboratories include this step in their shutdown procedures as a safety precaution.

Exercises (445):

1. Following is a list of shutdown tasks for the colormaster processor. Arrange them in the sequence in which they should be accomplished.

    a. Turn off the recirculation pumps.

    b. Turn off dry-box blower.

    c. Turn off main drive.

    d. Turn off dry-box thermostat.

    e. Turn off water.

    f. Insure replenishment valves are closed.

446. Given the recommended shutdown procedures for a processor and the order in which these procedures were conducted, indicate the probable harmful effects upon the processor.

Effects of Improper Machine Shutdown. In some cases, the sequence of shutdown steps is important to the life of the processor. In other situations, improperly sequenced shutdown steps could be detrimental to the quality of the material that will be processed in the future. Every time shutdown procedures are improperly conducted, the operator is taking a chance. This is why it is important for the operator to know the shutdown procedures and to execute them correctly.

It would be impossible to list all the effects of improper processor shutdown for all machines in this CDC. Instead, we emphasize the fact that great damage can be done to any processing system when the dry-box blower is turned off before the temperature reaches a safe level. Furthermore, shutdown procedures must be conducted to preclude any possibility of ruining the processing solutions contained within the system.

Exercises (446):

1. In column A below is the correct sequence for shutdown procedures for a leadered-type processor. Column B contains the sequence in which the shutdown steps were conducted. Refer to the text for objective number 445 as well as the preceding information to determine the results that could be expected for each step conducted out of sequence.

Column A

a. Decrease transport speed to 5 fpm.
b. Turn off main drive.
c. Turn off dry-box thermostat.
d. Turn off solution temperature control switches.
e. Turn off solution recirculation switches.
f. Check replenishment valves.
g. Turn off wash water.
h. Turn off dry-box blower.
i. Turn off main power.
j. Turn off breaker switches.

Column B

a. Turn off main drive.
b. Turn off solution temperature control switches.
c. Turn off solution recirculation switches.
d. Turn off wash water.
e. Turn off dry-box blower.
f. Turn off breaker switches.

4-3. Troubleshooting Black-and-White Processors

To function correctly and efficiently, a processing machine must be properly cared for and maintained. If maintenance is performed consistently and in accordance with approved procedures, little trouble should be experienced. On any processing machine, there are many adjustments which must be performed. You will find that these adjustments are not difficult, particularly if you follow the detailed instructions contained in the technical orders.

447. Use information from this and previous sections to indicate which sense (sight, hearing, or touch) is used to detect listed processor malfunctions.

Detecting Processor Malfunctions. Troubleshooting a continuous processor is that task which evaluates the performance of the processor in terms of operation and product quality. Every function on each system must operate in a specific manner. If it does not operate as designed, some recognizable symptom is evident. The most common symptoms are discussed below.

Hearing. This sense is used to detect any malfunction that produces unusual sounds. These might include, but will not be limited to, the improper meshing of gears, worn or improperly lubricated bearings, and loose or improperly lubricated drive chains.

Sight. At times, malfunctions are indicated by motions and indicators long before they affect product quality or stimulate a sense other than the eye. These malfunctions would include such things as would be indicated on the processor control indicators (temperature, replenishment rates, and speeds) and indicator lights as well as movements, such as a rising lift rod. Furthermore, some malfunctions can only be detected by a visual examination of the finished product. These would include scratches (continuous and repeating noncontinuous), developing streaks, and drying streaks.

Touch. At times, conditions might be such that the sense of touch is most advantageously used to detect malfunctions. This is especially true when total darkness is required to prevent material loss, and moving equipment parts are inclosed in some type of housing. Usually, defective bearings or bushings, or the need for lubrication of these parts, which are concealed by a housing, can best be detected by feeling for a buildup of heat.

Exercises (447):

The following list of processor malfunctions can be detected by proper troubleshooting. Determine if they could best be recognized by sight, hearing, or touch.

1. Improperly adjusted transport roller clutches.

2. Worn bearing in recirculation pump.

3. Uneven airflow from air squeegee prior to entering drying compartment.

4. Improperly lubricated motor.

448. Determine the cause of improper processor operations.

Using Troubleshooting Tables. Troubleshooting a continuous processor is not a difficult task. The manufacturer will usually identify the most common processor operating malfunctions, their probable cause or causes, and the procedure for correcting the malfunction. These are then produced in table form as illustrated in tables 4-1, 4-2, and 4-3.

The information given in table 4-1 is extracted from the *General Service Troubles Table* for a typical black-and-white narrow film processor as listed in the appropriate technical order. Table 4-2 is the same type information applicable to the Model 11C–MW "Versamat." Table 4-3 contains imagery discrepancies most commonly resulting from "Versamat" malfunctions; but in many cases, this information can be applied to other type processors.

As you will see when observing the tables, the information is arranged in three columns. The left column lists the trouble, the center gives the probable cause(s), and the right suggests the remedies. As an example, if the film catches in the narrow film processor magazine (table 4-1), the table lists four probable causes and at least one remedy for each. Once the trouble is identified, the operator must first refer to the troubleshooting table to determine the probable cause, and then execute the action necessary to correct the malfunction.

Exercises (448):

From the following list of undesirable processor conditions, indicate the probable cause(s) for each.

1. The required replenishment rate cannot be obtained on a "Versamat" 11C–MW.

2. No air circulation in the dry-box of a narrow film processor.

3. Small black spots on film.

4-4. Troubleshooting Color Processors

As with black-and-white processors, color processors must operate as perfectly as possible. Since we have already discussed troubleshooting procedures for black-and-white processors, let's look at the troubleshooting procedures for a typical color processor.

449. List the considerations the Air Force makes before purchasing equipment, and state why troubleshooting procedures are necessary.

Reasons for Troubleshooting. Every piece of equipment in an imagery production laboratory was designed to do a particular job in a specific way. Furthermore, this equipment was obtained by the Air Force because it needed the product that could be produced by that particular piece of equipment within the preestablished requirements of speed and product characteristics. In other words, the type product, the speed at which the product can be produced, and the desired product characteristics are the factors which are considered before Air Force equipment is purchased. For these reasons, it is only commonsense that each printer, processor, etc., must be maintained in such a way that it will function within these guidelines.

As equipment is used, it slowly deteriorates mechanically even with complete and competent maintenance. As this deterioration occurs, the greater the variation in functioning systems (as an example, the evenness of the air from one side of an air squeegee to the other). Add to this the fact that the larger and more complex the equipment, the higher the probability that a system will malfunction. Since most color processors are larger, have more tasks, recirculation pumps, etc., and usually must be controlled within closer tolerances of speed and temperature, the need for troubleshooting is much greater than with black-and-white continuous processors.

Exercises (449):

1. What factors are considered before the Air Force procures a piece of equipment?

2. Why is proper troubleshooting necessary?

3. Why is the need for troubleshooting color processors greater than for black-and-white processors?

450. Determine the probable cause of improper processor operations.

Troubleshooting the Color "Versamat." The procedures for using color processor troubleshooting tables are the same as for black-and-white processors. Furthermore, in the case of the "Versamat" series (both black-and-white and color models), many causes and remedies for given troubles are the same. Table 4-4 contains some of the data given in the technical order for the "Versamat" Model 1411. Compare this data with that contained in table 4-2 for the "Versamat" Model 11C–MW.

TABLE 4-1

TROUBLE	PROBABLE CAUSE	REMEDY
Motors do not run	Failure of power supply	Check supply source outlet.
	Faulty "START" button.	Replace "START-STOP" unit.
Pump and drive motor	Fuse burned out indicating short in motor or wiring.	Repair wiring or replace motor.
Drying cabinet blower motor.	Fuse burned out indicating short in wiring or short circuited blower motor.	Repair wiring or replace motor.
Loading elevator	Film catches in magazine. Elevator rollers stick.	Remove rollers, wash in trichloroethylene or solvent. Federal Specification P-S-661 and lubricate with oil, Specification Mil-O-6068.
Elevators other than loading elevator rise during operation	Rollers mounted on elevator in operational sequence ahead of the one giving trouble are too tight.	Remove offending rollers and replace, or sand flat surfaces to compensate for swelling.
	Top shaft clutch out of adjustment.	Clutch on top shaft should be loosened slightly by backing off clutch nut on end of shaft.
	Machine improperly threaded.	Check the threading of the machine by lifting elevators and pulling front strands straight out. This method will prevent tangling of the strands and with elevator in its top position, checking of the threading is simplified. Be sure the strands are not threaded outside either the front or back plate of the elevator.
Slack in film	Top shaft clutches out of adjustment	Tighten clutch on top shaft following the section where slack occurs slightly but not on end of shaft.

TABLE 4-1 (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Film catches in magazine.	An improperly made splice.	The splice when made should have the edges of both the upper and lower ends in close alignment. The film end should not be allowed to extend byond the staples of the splice.
	The roller mounted below the throat of the magazine does not rotate.	Remove roller by means of the drive pin which penetrates both sides of the casting. This drive pin is removed by means of a punch. Wash bearing in trichlorethylene or solvent, Federal Specification P-S-661, and lubricate with oil, Specification MIL-0-6068.
	The reel plate of magazine stud.	The reel plate should rotate freely on this stud. A few drops of oil, Specification MIL-0-6068, may be used as a lubricant, or in the case of damage to the reel hub, such burrs should be removed by means of a file.
	Magazine cover screwed too tightly to magazine.	If too much pressure is used in locking the magazine cover to the magazine by means of the magazine cover knob, this will tend to lock or bind the heel plate within the magazine. The cover should be placed in position and tightened only finger tight.
No power to the main drive chains and top shaft sprockets.	Transmission of gear reduction assembly not functioning.	Check pulleys and sprockets.
Alarm buzzer does not sound.	Fuse blown out.	Check with new fuse. If the new fuse burns out, immediatly check buzzer circuit wiring for short circuit.
Alarm buzzer does not sound (continued)	Improper adjustment of magazine alarm cam.	Reset magazine alarm cam.
Elevator alarm fails to function.	Placement of the limit switch or the contact between the elevator guide roller and the switch actuating cam.	Proper placement of the switch should allow for an opening or clearance of approximately 0.005 inch between the cam-actuated contractor and the switch. Use the film leader, which has a thickness of 0.005 inch, as a gage for checking this clearance.

TABLE 4-2

TROUBLESHOOTING TABLE—"VERSAMAT" 11C-MW

TROUBLE	PROBABLE CAUSE	REMEDY
Cocking or twisting of film in processing.	Feed tray out of alignment.	Adjust feed tray so that it is square with the detector rollers. Center tray to film opening.
	Rack turnaround assemblies out of adjustment.	Turnarounds must be secure to racks. Check show to master roller clearance. Check cluster roller clearance.
	Buildup on developer rack rollers.	Clean with System Cleaner.
	Squeegee or crossover assembly twisted or not seated properly.	Be sure all assemblies are square and seated properly.
Failure of film to transport in processing section.	Rack chain loose.	Adjust chain, tighten studs. Replace chain if adjustment is insufficient.
	Solution temperature too high.	Overheated solutions will cause film to become tacky.
	Binding in crossover. Unit hard to turn by hand.	All rollers must have sufficient end play to turn freely. Studs must be free of encrustation.
	Binding in rack (indicated by rack jumping up and down in tank). Unit hard to turn by hand.	All rollers must have sufficient end play to turn freely. If rack drive shaft or master roller drive shaft or turnaround is tight, replace bearing affected.

TABLE 4-2 (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Failure of film to transport in processing section. (continued).		Be sure unit is seated properly.
		Check squareness of unit.
		Inspect chain keeper for proper positioning.
	Crossover or rack rollers encrusted with heavy layer of chemical deposits.	Good housekeeping practices must be observed.
		Remove deposits with a plastic abrasive material.
		Developer rack may be cleaned with System Cleaner.
	Poor washing.	Insufficient water pressure.
		Insufficient recirculation pump pressure.
	Low solution level.	Leak at any of the plumbing joints.
		Check to see that drain valve is completely closed.
		Solution not being properly replenished.
	Improperly mixed solutions.	Mix solutions according to directions on package.
Failure of film to transport in dryer	Rollers binding in dryer entrance or exit crossover assemblies.	Free rollers so that they spin freely.
	Improper spacing between cluster roller and master roller of exit crossover.	Check spacing between rollers.

TABLE 4-2 (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Failure of film to transport in dryer (continued)	Warped cluster roller in exit crossover	Rollers must not come in contact with master roller.
	Transport rollers dirty.	Wipe with damp rag.
	Transport rollers not seated in holders.	Be sure bearings are seated properly in holders.
	Dryer temperature incorrect.	Set thermostat as recommended. Check with thermometer of known accuracy.
	Dryer air tubes improperly positioned or located.	Be sure to snap tubes into locking position when they are installed.
	Ambient conditions unfavorable, resulting in tacky film.	Turn up dryer temperature in five degree increments. If 140°F is insufficient, the need for air conditioning is indicated.
Lower than normal solution recirculation rate.	Foreign particle in solution pump.	Remove obstruction. Pay particulat attention to pump outlet.
	Heat exchanger clogged.	Clean. If some recirculation is present, System Cleaner may be used.
	Tubing in recirculation system clogged.	If chemical deposits are present, clean developer rack, tank, and recirculation system with System Cleaner. If foreign particle is lodged in tubing, it must be removed.

TABLE 4-3

TROUBLE	PROBABLE CAUSE	REMEDY
Scratches lengthwise on emulsion side of film.	Plastic film guide on entrance crossover assembly warped or buckled.	Remove crossover assembly, inspect plastic film guide for warping or buckling and replace or trim as necessary.
	Metal burr on feed tray.	Inspect feed tray for burring and remove with emery cloth if evident.
Random lengthwise scratches on either the smulsion or base side of film.	Stopped or hesitating rollers or incorrect spacing between rollers.	Remove racks, turn main gear and check each roller for hesitation. Clean if chemical crystallization exists. Reinstall and check rack drive chain for condition and proper tension. Check for silver build-up and clean if necessary. Check clearance between cluster rollers and master roller. Check clearance for the top cluster roller to the entrance crossover. Check top cluster roller to master roller clearance on the exit crossover.
Small black-spots on either side of the film.	Silver build-up on the rollers in developer racks.	Remove racks and clear

TABLE 4-3 (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Drying streaks on film.	Dirty air-tube slits	Clean interior of air tubes with warm water.
	Slit width not maintained properly.	Readjust air slits to proper width.
	Dryer temperature too high.	Adjust temperature.
Decrease in film density.	Developer reaching exhaustion.	Check replenishment rate and/or mix fresh solution.
	Old or exhausted replenisher.	Mix new solution.
	Developer temperature low.	Adjust developer thermostat as recommended.
	Developer solution diluted with water or improperly mixed.	Follow instructions when mixing. Check for leak in heat exchanger. Change developer.
Increase in film density.	Developer temperature too high.	Adjust thermostat as recommended.
	Over-replenishment.	Check replenishment rate.
	Replenisher improperly mixed.	Mix according to directions.
Fogged film.	Light leak around top or wall.	Seal the cover firmly and check for light leaks at wall.
	Developer contaminated with fixer.	Drain and rinse tanks. Always use splash guard when removing racks.

TABLE 4-4

TROUBLE	PROBABLE CAUSE	REMEDY
Cocking or twisting of film in processing section.	Burrs on crossover or turnaround shoes.	Tips of all guide shoes must be free of burrs.
	Rack turnaround assemblies out of adjustment - cluster rollers and shoes.	Turnarounds must be secure to racks. Check clearances between shoes and rollers.
	Chemical buildup on rack rollers.	Clean as instructed in "EA-4 Process Maintenance".
	Squeegee or crossover assembly twisted or not seated properly.	Be sure all assemblies are square and seated properly.
	Worn rack studs.	If studs are worn slightly or if they appear to be bent downward, their life may be prolonged by rotating one-half turn. If wear is excessive, replace.
Failure of film to transport in processing section.	Rack chain loose (indicated by hesitating rack rollers).	Adjust chain, tighten studs, replace chain if adjustment is insufficient.
	Solution temperature too high.	Overheated solutions will cause film to become tacky.
	Crossover or turnaround roller out of place.	Gear teeth must mesh with teeth of larger gear.

TABLE 4-4 (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Failure of film to transport in dryer. (continued)	Dryer transport rollers hesitating. (continued)	Must have sufficient end play to turn freely. Ball bearings must turn freely.
	Dryer temperature	Set thermostat as recommended.
Lower than normal solution recirculation.	Foreign particle in solution pump.	Remove obstruction.
	Tubing in recirculation system clogged.	If chemical deposits are present, clean developer rack, tank, and recirculation system. If foreign particle is lodged in tubing, it must be removed.

Exercises (450):

Using table 4-4, determine the probable causes for the following improper processor operations.

1. The film does not track correctly.

2. Failure of film to transport in dryer.

4-5. Keeping Processors Clean

Preventive maintenance on any piece of photographic equipment begins with its physical state of cleanliness. This does not mean that a spotless processor will continue operating indefinitely. But statistically, it has been proved that a processor that is kept clean produces fewer material physical defects, which in itself, results in shorter downtimes for maintenance functions.

As before, the procedures for cleaning every type of processor in the Air Force's inventory cannot be included in this CDC. Instead, we will again use as an example the most common black-and-white wide film processor. This is the "Versamat" 11C-MW.

451. Given a list of preventive maintenance functions, state the probable harmful results if these functions are not accomplished.

Cleaning the "Versamat." Each time the processor is shutdown, you must remove all processing section crossover assemblies and rinse them with warm water, because material or chemical buildup on them will cause scratches and film abrasions. If any deposits have formed, use a soft brush to remove them. Be sure you handle the crossovers with care. Wipe off all rack rollers above the solution level. The feed rollers of the entrance roller assembly should also be wiped off. Turn off all machine electrical switches and turn off the main power switch. It is advisable to prop open the processing and dryer section covers to vent chemical fumes. Also turn off the water supply.

After a week's operation, the cleaning procedure is more involved than for overnight shutdown. The following procedure is suggested.

(1) Remove, wash with water, and wipe off all rollers of the crossover assemblies.

(2) Check the tension of the rack chains. Any roller hesitation indicates a loose chain.

(3) Remove the roller racks. The splash guard should be used when pulling the fixer rack to avoid contamination of the developer. Wash all racks with running water which is not more than 120°F. Be sure to clean all chemical deposits on the sides of the racks, around gears on the chain tightener, etc.

(4) Rotate the rollers by hand and make sure they turn freely. Adjust chain tighteners if necessary.

TABLE 4-4 (cont'd)

TROUBLE	PROBABLE CAUSE	REMEDY
Failure of film to transport in processing section. (continued)	Master roller bearing worn.	Replace master roller bearing. Wear most common in drive side.
	Binding in crossover. Unit hard to turn by hand.	All rollers must have sufficient end play to turn freely. Studs must be free of encrustation.
	Poor washing.	Insufficient water pressure.
		Clogged strainers in mixing valve or water line filters need changing.
	Low solution level.	Leak at any of the plumbing joints.
		Check to see that drain valve is completely closed.
		Solution not being properly replenished.
Failure of film to transport in dryer.	Rollers binding in dryer entrance or exit crossover assemblies.	Free rollers so that they spin freely and easily.
	Master roller on exit crossover not turning.	Replace bearing.
	Warped cluster roller in exit crossover.	Rollers must not come in contact with master roller.
	Transport rollers dirty.	Wipe with damp rag.
	Badly warped transport rollers.	If warping is apparent, replace.
	Dryer transport rollers hesitating.	Check seating of transport rollers.

(5) Check all racks to make sure they are not twisted. Twisted racks cause slack buildup and consequent wraparounds. To check them, place each rack on a flat surface. Any twist will be apparent.

(6) Turn on the recirculation pumps and watch for surface turbulation of the solutions in the tanks to verify pump operation.

(7) Examine the solutions in the tanks for clarity and presence of foreign particles.

(8) Reinstall racks and crossovers. Check all gears to make sure they are properly seated.

(9) Check the dryer entrance crossover, the dryer exit crossover, and the multiroll squeegee assembly for proper seating.

(10) Inspect dryer air tubes. If slits are clogged, inform maintenance personnel. Also, make sure that the dryer air intake screen is clear of obstructions. Clogging and obstructions of air tubes result in uneven drying.

Exercises (451):

Following is a list of tasks that should be accomplished during cleaning of the "Versamat." State the possible harmful effects that might occur if these tasks are not accomplished.

1. Failure to clean the crossovers.

2. Not using the splash guard when pulling the fixer rack from the processor.

3. Not checking each rack to insure it is not twisted.

4. Failure to inspect air tubes.

452. Given a list of processor malfunctions, indicate what preventive maintenance might have prevented them.

Use of Acid Cleaners. Daily or weekly cleaning of processors is not sufficient to insure the highest state of cleanliness at all times. Periodically, the solutions within the processor must be drained. This may be required because of the need for maintenance. Or it may be required because the solutions are contaminated, overreplenished or underreplenished, or contain too much dust, dirt, or other foreign material.

With proper replenishment, "Versamat" solutions can last indefinitely. However, it is usually necessary to thoroughly clean the machine and perform preventive maintenance at the same time. Solutions are discarded at this time. A complete cleaning procedure may be your job. Such a cleaning is expedited by the use of a cleaner such as the manufacturer recommended, "Kodak Developer System Cleaner." Do not use cleaner in the fixer system. (CAUTION: *The cleaner contains sulfuric acid which can cause burns. Do not get it in eyes, on skin, or on clothing. In case of contact, flush skin or eyes with water for at least 15 minutes. Get medical attention for eyes.)*

You should follow these steps when cleaning the processor:

(1) Drain the developer and remove the developer racks.

(2) Install the splash guard to prevent contamination of the fixer if the fixer is to be retained.

(3) Remove the developer system filter cartridge and replace the filter cover, because the old filter can retain a sufficient supply of System Cleaner to contaminate fresh developer in freshly cleaned processor.

(4) Fill the two developer tanks with about 10 gallons of premixed cleaner.

(5) Turn on the developer recirculating pump and let the cleaner recirculate for about 15 minutes.

(6) Thoroughly flush the developer racks with warm water. Apply cleaner to the racks with a brush or spray bottle. Rotate the rack drive while applying cleaner to rollers and sideplates.

(7) Flush the racks with warm water and wipe rollers with a damp sponge to remove cleaner. Make sure rollers are thoroughly cleansed of System Cleaner.

(8) Clean the number 2 and number 3 crossovers as you did the racks. (CAUTION: *Use goggles or other eye protection when brushing cleaner.)*

(9) Drain cleaning solution from the developer tanks and flush with warm water.

(10) Replace racks and fill the developer tanks with warm water. Turn on the recirculation pump and the main drive. Run the machine for 5 minutes. Drain the tanks and repeat this procedure until the water is free of discoloration.

(11) Install a new developer filter cartridge and mix new developer solution unless other maintenance is required at this time.

(12) The fixing bath system can be cleaned with just warm water in a manner similar to the developer system *except that the developer cleaner is not used.*

Exercises (452):

1. The fresh developer certifies in the storage tank. However, after being recirculated in the processor that had just been cleaned, it will no longer certify. What probably happened?

2. At the beginning of the day, the developer solution for one of the processors will not certify. Normal weekly cleaning was performed the night before. What is the probable reason for this?

4-6. Seasoning the Processor

In some laboratories, seasoning of the processor developer solution tanks is performed. While this task is not actually part of the processor cleaning procedures, if it is *accomplished at all, it must be done as the last step prior to* refilling the tanks with certified solutions.

453. Explain what discrepancy may result if proper tank seasoning is not done after acid or special tank cleanup.

Why Seasoning Is Necessary. Seasoning solution tanks consist of filling the tanks with developer solution, usually uncertified, and recirculating it for a given period of time. This action is to prevent dichroic fog from being formed on the film during subsequent processing. Dichroic fog appears as a two-colored sheen and resembles grease or oil on the film. Also, if tanks are not seasoned, the cleaning solution may not be completely removed by rinsing. This causes the developer to be excessively acidic and thus to have a decreased pH. The process gamma would then be decreased because of the low pH. After the seasoning process, the seasoning developer is drained and the tanks are filled with certified developer solution.

At this point, there might be some confusion as to why uncertified developer is used to season the processor developer tanks. It is not absolutely required that uncertified developer is used. But let's consider some facts. First, the only requirement is that the solution used to season the tanks be the same as that which will be used for actual material processing. Second, quality assurance personnel spend considerable time certifying newly mixed solutions. If these solutions do not certify, additional time is spent analyzing them, and, when possible, making adjustments to bring them within standards. Third, once the seasoning solution is recirculated for a time, it is dumped. You should see from these three reasons that, economically, it is more feasible to use uncertified developer. It contains all of the constituents of the certified solution, it is going to be dumped, and quality assurance personnel have not spent excessive time in certifying, analyzing, and balancing it.

If dichroic fog forms on valuable original negative material, the deposit can sometimes be wiped off the negative while wet. However, once it dries on, it may be a little stubborn. The fog can be removed by rinsing the negative(s) in a neutral solution of potassium permanganate (one-half gram per liter) until the fog has disappeared. Then the negatives are immersed in a 5-percent solution of sodium bisulfite until the brown stain is removed. This procedure may not be feasible with continuous lengths of aerial film, but could be used when select prints are required.

Every task in continuous imagery processing should be done in a predetermined sequence, written or understood. Seasoning of the developer tanks is no exception. If this one task is not done properly, then all your efforts and time have been wasted.

Exercises (453):

1. What might be the result to the material being processed if developer solution tanks are not seasoned after acid cleaning.

2. If developer tanks are not seasoned after acid cleaning, the characteristics of the developer solution might also change.

   a. What will these changes be?

   b. What would cause these changes?

4-7. Purging Color Chemical Systems

The methods for purging and seasoning color processing systems are, in many respects, identical to those used for black-and-white processing systems. As with black-and-white systems, foreign matter, particularly lint and dirt, are ever-present elements which present a threat. In a continuous imagery processing operation, provisions must be made to take advantage of every opportunity afforded to clean and maintain the entire processing system.

454. Name the solutions that should be used to clean and to season each of the tanks of color processors.

Seasoning of Color Processors. As previously stated, seasoning of any processor solution tanks is done only after thorough cleaning. For this reason, let's first of all look at the manufacturer's recommended cleaning procedures for a typical color processor. Again, we will use as an example the "Versamat" Model 1811.

It is suggested that the prehardener racks of the "Versamat" be cleaned with glacial acetic acid. This acid should be squirted on the rollers and then rubbed lightly with a plastic abrasive cloth. Before returning these racks to their tanks, they must be rinsed thoroughly with water.

Both developer and the fixer rollers should be cleaned with Kodak System Cleaner. Instead of immersing the entire racks into the System Cleaner solution as is common with black-and-white processing systems, it is preferred that the solution be squirted onto the parts. This treatment and light rubbing with a plastic abrasive cloth will clean the rack. Again, it is important that the System Cleaner be completely removed from the racks before they are returned to the tanks.

It is not recommended that developer and fixer tanks be filled with glacial acetic acid or the System Cleaner. Instead, the cleaning solutions are squirted directly onto the tank walls, allowed to set for a period of time, and then rinsed in fresh water.

The tanks which hold the stop baths, neutralizer, bleach, and wash water will remain relatively clean. Foreign matter accumulated in the bottom of these tanks can be gotten rid of by periodic dumping and flushing the tanks with warm water. The blue color which appears on the bleach and fixer racks and in the tanks can be removed by squirting a 10-percent sodium hydroxide solution on the surfaces, then flushing thoroughly with water.

The procedure for seasoning the color "Versamat" tanks is the same as that for seasoning the tanks of a black-and-white processor. Again, uncertified chemicals should be used and these chemicals must be identical to those formulas used during actual mission film processing. Not all tanks need to be seasoned, however, and the particular tanks to be seasoned depend upon the requirements of each individual laboratory.

Exercises (454):

1. List the solutions that should be used to clean the following color "Versamat" tanks:

   a. First developer.

   b. Color developer.

   c. Bleach.

   d. Prehardener.

2. What solution would be used to season the tanks listed in exercise 1 if required?

455. Specify when replenishment and recirculation systems are seasoned, and what solutions are used for seasoning.

Purging the Replenisher and Recirculation Systems. Part of the cleaning process for any developing system is a periodic purging (cleaning) of the replenisher and recirculation systems. If chemical cleaning solutions are used during this task, these systems must also be seasoned. Otherwise, the new processing solutions will be contaminated with the cleaning solutions as they are pumped to the processor, or recirculated through the recirculation system. The following paragraphs apply to monitoring the replenisher and recirculation systems of the color "Versamat."

The cleaning of these two systems should precede the cleaning of the machine tanks. Generally, hot water is used for this cleaning.

However, if either of these systems has been contaminated with oil, grease, or other foreign matter, a 1-percent solution of trisodium phosphate should be used.

The first step in cleaning the replenishment system is to drain all the replenisher solutions from the machine tanks and the holding tanks. The chemical line screens should then be cleaned and returned to the strainer holder. Next, fill the replenisher holding tanks to the half-full mark with hot water or a solution of trisodium phosphate, then scrub the interior of the tank with a stiff brush. Pump several gallons of this solution directly into the sewer, and the remainder through the replenisher system into the machine through the machine quick-fill. If the recirculation system is to be cleaned, retain the cleaning solution within the tank and use it to clean this system. Drain the tanks, remove the flowmeter tubes, and clean with water and brush. After replacing the flowmeter tube, rinse the replenisher and recirculation systems several times with water. The strainer should be rechecked at this point.

The above procedure is applicable to all holding tanks and replenisher systems. In addition to this treatment, the prehardener tank will probably need additional attention. A relatively insoluble material forms on the walls of this holding tank. This tank may be cleaned by squirting glacial acetic acid onto the sides of the tank and scrubbing with a stiff brush or plastic abrasive cloth. Once again, this tank must be thoroughly rinsed with water before refilling.

During cleaning of the recirculation system, allow the solution to be heated to the normal operating temperature while the cleaning solution is being recirculated. As foreign matter collects on the solution surface, add water to overflow it. Continue this procedure until little or no foreign matter is noted. Then drain the tank and season.

Exercises (455):

1. When is it necessary to season replenishment and recirculation systems?

2. What solution is generally used to clean replenishment and recirculation systems?

3. How are contaminents such as grease removed from replenishment and recirculation systems?

4-8. Corrosion Control

The last item to be covered in this chapter is corrosion control of processors. This does not mean that it is the least important of all the tasks discussed. Instead, it is one of the most important if the equipment is to last for an extended period of time. Even with the most conscientious cleaning efforts, some chemical residue will usually remain, or entire areas of dried chemicals will be missed which will result in corrosion.

456. Specify the procedures for corrosion control on processors.

Procedures for Corrosion Control. Due to the wide scope and variety of corrosion, only a few general guidelines can be given here.

Steel. Steel parts or surfaces which show corrosion deterioration may be cleaned by a sodium hydroxide rust-remover solution. Heat resistant steel alloys and most nickel alloys may be cleaned with the same solution.

CAUTION: *Aluminum, zinc, or tin alloys must not be cleaned with alkaline cleaners since this cleaner will damage these materials.*

Aluminum. Corrosion may be removed from aluminum alloys by a light blasting. Both dry and vapor blastings are acceptable if precautions are taken to prevent the loss of the base metal. Aluminum cleaners or fiber brushes may be used on anodized aluminum if the anodic film is not penetrated, especially in laboratory areas where blasting is not allowed.

Copper. Copper and copper alloy bushings and pipes may be freed of tarnish or green stains by immersion for a few seconds in an aqueous solution of chromic acid.

Silver. Brown or black tarnish on silver has no corrosive properties. This tarnish can easily be removed by contact with a piece of magnesium or aluminum immersed in a warm water solution of a household detergent. Common table salt with baking soda may also be used. These parts should be thoroughly rinsed and dried after treatment.

Exercises (456):

Describe how corrosion may be removed from the following items:

1. The stainless steel side panels of a processor.

2. Chemical recirculation lines made of bronze (an alloy of tin and copper).

3. Aluminum tops for the chemical tanks.

457. Describe the significance of corrosion control violations, and indicate the probable results of a given violation.

Results of Corrosion Control Violations. More damage can result from improperly applied corrosion techniques than if no attempt had been made for such control. Each operator should be familiar enough with the processor to know what parts are stainless steel, copper or copper alloy, etc. New personnel and those that are not knowledgeable about processors should research the applicable technical orders and determine the manufacturers' recommended corrosion control procedures if listed. Only by such research can they become competent in this task.

Exercises (457):

1. What is the significance of corrosion control violations?

2. What would be the probable results if aluminum chemical line connections were cleaned with a rust remover solution? (See CAUTION under Objective Number 456.)

Nonconventional Image Systems

IN PREVIOUS sections of this CDC, we have discussed conventional rollfilm processing. This type processing is used for the majority of the production work accomplished in the imagery production. However, there are other methods by which photographic images may be satisfactorily produced. A discussion on the more common of these methods is the objective of this chapter.

5-1. Nonconventional Processing

Time, or rather the lack of it, is one of the greatest handicaps that any laboratory works under. It would be misleading for us to say that you will always have plenty of time to get things done. Photographic missions are becoming more numerous, and the demand for the completed product is becoming greater. Thus, there is a need for a rapid processing system. Among the many reasons for rapid processing systems is the need to process strike film from a fighter aircraft. Here the film must be evaluated by the intelligence people without delay, and the processing facility must be able to furnish a quality product in the shortest possible time.

458. Describe the characteristics of the "Viscomat 1792" processor.

The "Viscomat" Processor. To fill the need for a rapid processing ~~exposure station through a pair of pressure rollers. These rollers~~ system, the Air Force employs processors similar to the Eastman "Viscomat." In size and design, the "Viscomat" processing system is totally different from the processors we have studied thus far. The "Viscomat" is 60-inches high, 24-inches wide, and 18-inches deep, requiring only 3 square feet of floorspace for operation. Compare these dimensions to those of a typical spray processor with dimensions of 130-inches long, 30-inches wide, and 59-inches high, and you can see the difference in size. Also, the "Viscomat" is designed in a vertical format instead of the horizontal format of the previous processors. (See fig. 5-1.)

The most important difference between "Viscomat" and the previous processing systems we studied is the manner in which processing takes place. You recall that in the immersion system the film is immersed in the solutions, and that in the spray processing system, the solutions are impinged upon the surface of the film. In the "Viscomat," processing is accomplished by the application of a thin layer of viscous solution to the emulsion of the film. The film moves through a water vapor saturated atmosphere whose temperature is 130°F., which causes the developing agents in the viscous material to penetrate the emulsion. (See fig 5-2.)

The "Viscomat" processor can be used with two types of viscous photographic solutions, each applied in a similar manner. The first type is the normal two-solution process consisting of a developer and a fixer. The second type is a monobath. A monobath contains both the developer and fixer in one solution. Thus, during processing, both development and fixation take place at the same time. These two systems will be discussed in greater detail in the next objective.

In its chemical supply system, the "Viscomat" processor has storage space for containers of developer, fixer, and monobath. The change from one mode of operation to another—from two-solution processing to monobath processing, for example you—merely select the desired switch and insert a probe into the proper container. The solution(s) flow through the probes into pumps and are pumped to the selected coating hoppers. When a container is empty, you simply replace it with a new container of solution.

Exercises (458):

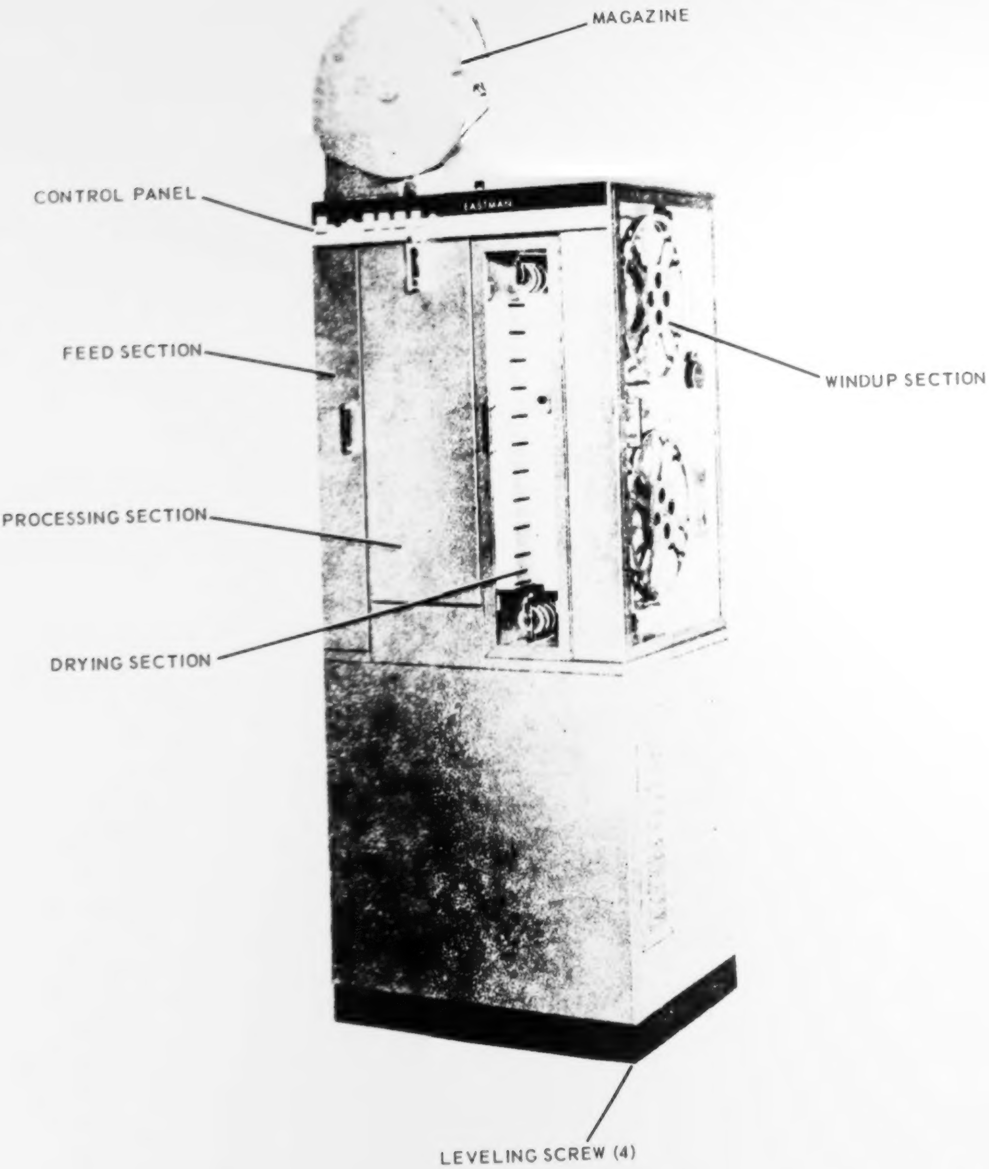
1. What is the main difference between the "Viscomat" and conventional rollfilm processors?

2. What two chemical processing systems can be used with the "Viscomat" processor?

459. Specify which "Viscomat" processing method should be used for maximum accessibility of the product.

Principles of Operation. To understand the principles of operation for the "Viscomat" processor, let's look first at its operation during two-solution processing and then at its operation during monobath processing.

Normal (two-solution) processing. In the normal processing mode for processing negative or positive film, the exposed film is drawn from the lighttight magazine on the top of the processor and spliced to the leader threaded



MAGAZINE
CONTROL PANEL
EASTMAN
FEED SECTION
WINDUP SECTION
PROCESSING SECTION
DRYING SECTION
LEVELING SCREW (4)

Figure 5–1. The "Viscomat" processor.

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on the rollers in the feed section (fig 5-3). After the film has passed through the feed section, it enters the processing chamber. In the processing chamber, which is also lighttight, a specially designed developer coating hopper spreads a thin layer of viscous developer evenly over the emulsion of the film.

While the film passes up and over the adjustable roller, the viscous developing solution is doing its work. The film then passes around the adjustable roller and back down to the roller at the bottom of the chamber. While the film is passing around this bottom roller, the coating of developer is removed by a spray of water from the cutoff spray jet.

After passing through an air squeegee, to remove any remaining water, the film passes the fixer coating hopper which applies a coating of viscous fixer to the emulsion side of the film. The film travels through three complete loops while coated with fixer and then enters the spray-wash section. After being washed thoroughly, the film passes through the drying section and on to the takeup section where it is lubricated (if desired) and wound up onto takeup reels.

During two-solution processing, the processor is operated at a set speed of 36 feet-per-minute. The maximum times available for each treatment are as follows:

- Development ....6.5 second.
- Fixation ....17.0 second.
- Washing ....15.0 second.
- Drying ....22.0 second.

The total time for the operation, or for a specific portion of film to go from dry to dry, is then approximately 60.5 seconds.

Monobath Processing. When the processor is used for negative processing with the monobath solution, the film travel path is the same, except that the cutoff water spray roller and the air squeegee are not used. In monobath processing, the fixer coating hopper is not used.

When the film enters the processing chamber from the feed chamber, the developer coating hopper coats the emulsion of the film with a thin (approximately 0.16 inch) layer of monobath solution. Monobath processing is accomplished at a film travel speed of 18 feet-per-minute, which gives you the following treatment times:

- Monobath ....47 seconds.
- Washing ....30 seconds.
- Drying ....44 seconds.

The total dry-to-dry time for the monobath operation 121 seconds.

Exercises (459):

1. Which chemical system should be used when accessibility of the product is of prime importance?

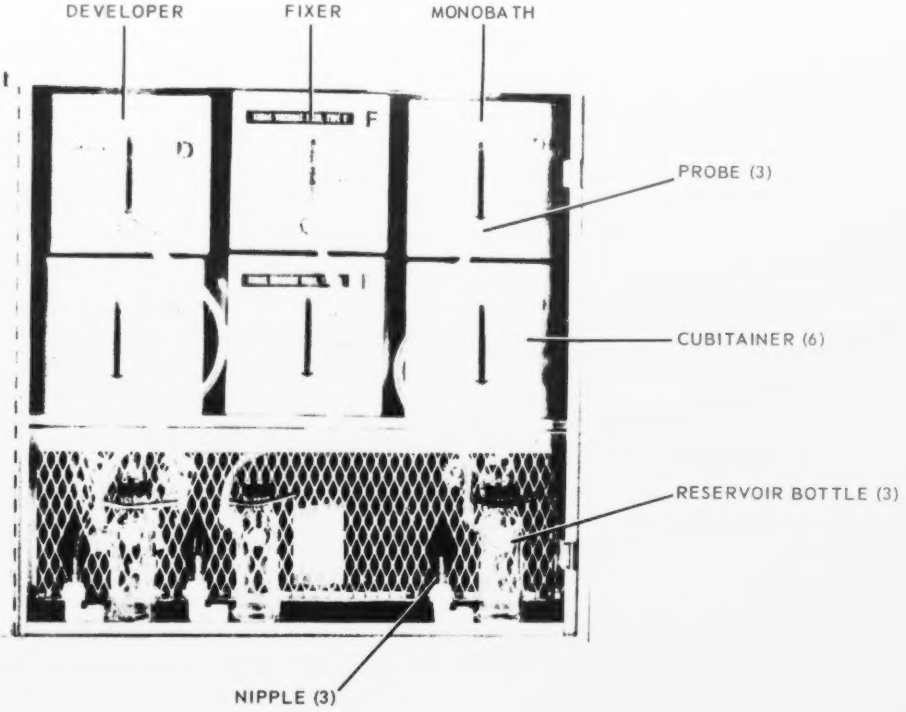
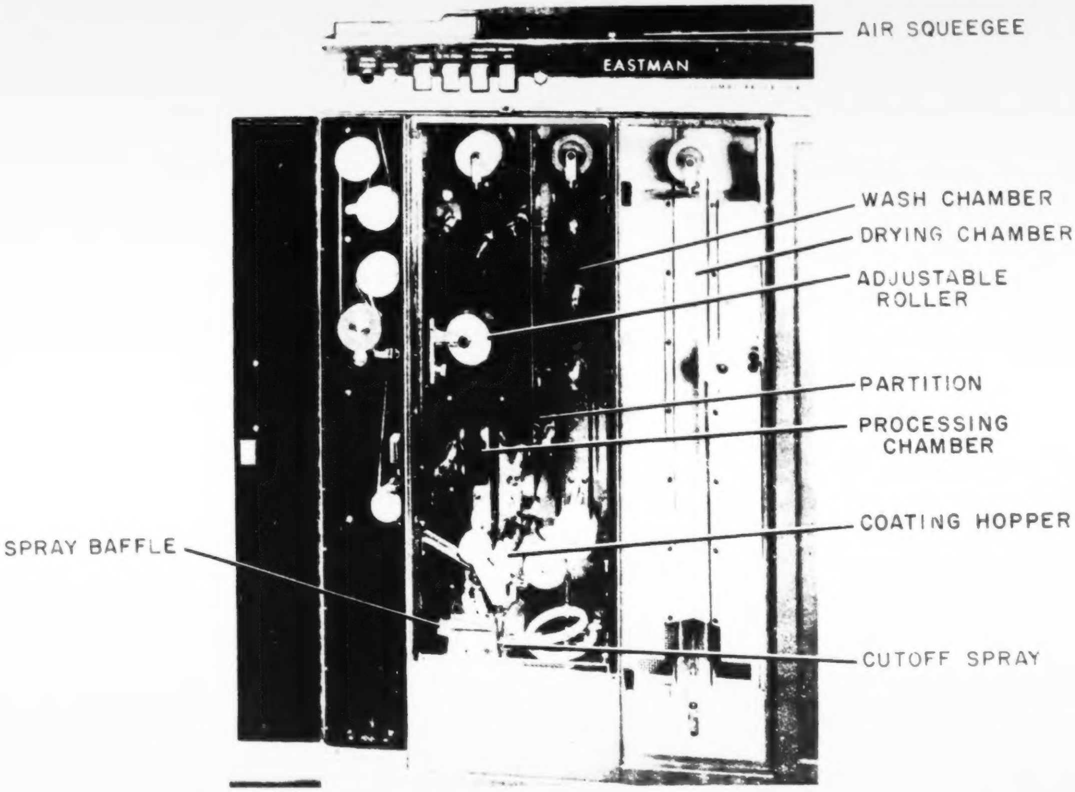


Figure 5-2. Chemical supply system, "Viscomat" processor.



2. The fixer coating hopper is not used with which chemical system?

460. Given situations that might occur during "Viscomat" operations, determine the probable cause.

Chemical Solution Timers. Because the processor employs containers of solution rather than a replenishment system such as that on the spray processor, you must have some means of knowing when you need to change solution containers. The processor is equipped with a two-solution timer and a monobath timer located in the rear compartment of the processor. There are other indicators and controls located in the rear compartment of the processor. These are the cabinet temperature gauge, the input water pressure gauge, the fixer rinse lever, the monobath rinse lever, the developer rinse lever, the cabinet rinse lever, and the solution selection lever. Also located in the rear compartment is a filter slide, which contains the filter used to remove particles from the air being supplied to the drying chamber of the processor. All of these indicators and controls are used to monitor specific operation functions of the processor. To prepare the processor for operation, you must insure that a specific water pressure, a specific cabinet temperature, a specific air pressure, and a specific recirculating water pressure are maintained. (See fig. 5-4.)

The purpose of the developer rinse, fixer rinse, and monobath rinse is to rinse out the solution lines for the various chemicals. The cabinet rinse is used to rinse the processing and wash chambers. These are used when the machine has been shutdown or when you are changing from a two-solution process to a monobath process, or vice versa. These valves are closed during normal operation.

Located at the bottom of the rear compartment is the solution selection lever. This lever is used to select either the two-solution or monobath process; it activates the solution supply lines for the solution selected. It is interconnected with a single/dual switch on the control panel which activates the pump or pumps, depending on the process desired. The settings of the solution selection lever and the single/dual switch on the control panel must be identical—*either mono- bath and single, or dev and dual*. If this is not done, a pilot lamp at the right of the pump ON-

OFF switch on the control panel illuminates. The illumination of the pilot lights warns you that solution is not being pumped to the hoppers.

Operating the Processor. To operate the processor for the development of an original negative, proceed by setting the warmup period, selecting the process, and determining the developing time.

Warmup period. The processor requires a 10 to 15 minute warmup period to allow the temperature of the processing chamber to stabilize. The thermometer in the rear compartment indicates when the proper temperature is attained. During the warmup period, the processing and drying sections reach operating temperature, and the atmosphere of the processing section becomes saturated by tempered water from the wash spray nozzles.

Set the OPERATE/WARMUP switch on the control panel at the OFF position. Turn on the electrical power at the wall switch and turn on your tempered water supply. When you have applied the power to the machine, the red pilot lamp lights and the wash spray and feed-cabinet blower operate.

Allow 1 minute for the sump to fill. Now press the OPERATE/WARMUP switch to WARMUP to activate the sump water recirculating pump, the air compressor, and the two dryer blowers. The switch also starts the dryer heater, provided that the adjustable thermostat located in the takeup section calls for heat. The dryer pilot lamp on the control panel lights only when the dryer heater is operating.

During the warmup period, press the WINDUP switch in the windup section of the processor to the upper or lower position, depending upon which windup spindle is to be used. The center position of the switch is the OFF position. If the film is to be lubricated during takeup, fill the plastic lubricant bottle and lower the idler spool to its preset stop. The lubricant feeds from the bottle to the reservoir and is then picked up by the nylon plush-covered lubricator, which rotates counterclockwise and transfers the lubricant to the film.

Process selection. Check the processing instruction sheet supplied by your quality assurance section for the film to be processed. Then, set the control panel switches for the machine speed (18 or 36 feet-per-minute) and the number of solutions (single or dual) to be used. Also set the process selection valve in the rear compartment at either DEV (two-solution) or MONO (monobath).

Development time. For a two-solution process, you can vary the development time from approximately 2½ to 6½ seconds by moving the adjustable roller on its calibrated track.

This increases or decreases the length of time required for a print on the film to travel from the developer coating hopper to the cutoff water spray. For the monobath process, set the roller at the top of the track.

Final Check. Before you actually begin processing you should make a final check of the following items:

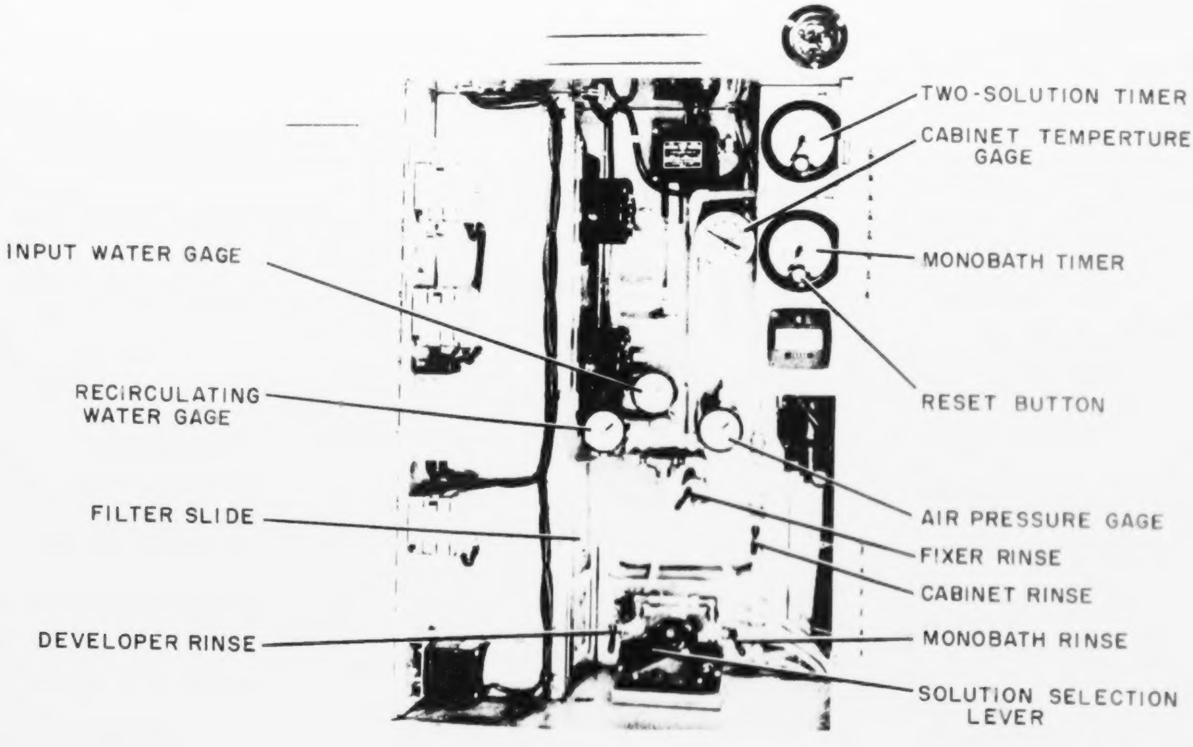


Figure 5–4. Rear compartment, "Viscomat" processor.

a. Processing section.
(1) Threading—monobath or two-solution
(2) Fixer hopper—monobath or two-solution
(3) Development—time-setting
b. Lower rear cabinet.
(1) Solution containers—position and connections.
(2) Solution in reservoir bottles.
c. Upper rear cabinet.
(1) Water gauges—18 to 22 psi.
(2) Air pressure gauge—5 to 6 psi.
(3) Processing temperature (± 1/2°F.).
(4) Process selector value—monobath or two-solution.
(5) Rinse valves—closed.
(6) Timer setting.
(7) Dryer filter—slide open fully.
d. Windup section.
(1) Dryer thermostat setting—see film processing sheet.
(2) Windup switch—upper or lower.
(3) Windup reels installed.
(4) Leader threaded to reel.
(5) Film lubricant supply; idler-spool setting.
e. Control panel.
(1) Operate/warmup Switch—at WARMUP.
(2) Speed Switch—at 18 or 36 feet-per-minute.
(3) Solution pump switches—
(a) Single/Dual—single or dual.
(b) ON/OFF—at OFF.

When you have made these checks and have verified the correct settings, press the solution pump switch to the ON position and press the OPERATE/WARMUP switch to the OPERATE position. The processor now begins operation. If the processor fails to start, depress the START switch and hold it in for several seconds. This takes up slack in the leader and bypasses an electrical interlock.

Processing continues automatically until the supply of film in the magazine is exhausted. When the end of the film pulls free in the magazine, the loss of film tension causes the end-of-film detector roller in the supply chamber to move downward and open a switch. This energizes a magnetic brake which stops the pacer roller and shuts down all electrical components except the feed cabinet blower and the red pilot lamp. When this happens, press the OPERATOR/WARMUP switch to the OFF position. Another magazine of film (or leader) must be spliced to the end of the leader in the supply cabinet.

To connect film (or leader) from the magazine to that in the machine, rest the magazine on top of the processor and pull several inches of film from the magazine. Then, make a butt splice using splicing tape.

Align the films directly over each other (base to base or emulsion to emulsion) and cut the ends squarely. Be sure not to cut through perforations. Careful alignment and a thin splice are important, since they insure proper tracking and smooth passage of the film past the coating hoppers.

After splicing, draw the loop of film into the processor by starting the machine. When the film is taut, lower the magazine slowly and latch it in position. You may then continue processing. When all of the film to be processed has been processed, splice on the magazine or leader to rethread the machine. When the leader reaches the takeup section, shut off the processor.

Exercises (460):

1. The monobath time indicates a solution running time of 18 minutes. You have a 400-foot roll of film to process. Is this sufficient solution for this processing run? Why?

2. During operation of the "Viscomat," the pilot light to the right of the ON-OFF switch comes on. What does this indicate?

3. After proper warmup, the start switch is depressed, but the "Viscomat" does not start operating.

   a. What should you do?

   b. Why should you take this action?

4. The end of the film leaves the magazine and is transported completely through the "Viscomat" processor to the takeup reel without the transport mechanism being stopped. What could cause this situation?

5. Film from a magazine does not track properly on the "Viscomat" processor even though the film from the previous magazine did. What could cause this mistracking?

461. Briefly describe an electrostatic nonsilver image system.

Electrostatic Nonsilver Image System. Considerable experimentation has taken place in the area of electrostatic photography. This system is now widely used for copying, reproducing from microfilm, and for printing aerial negatives.

The system is divided into the transfer and nontransfer systems. In principle, the direct electrostatic process is very similar to the transfer process. The main difference is that, in the direct method, the electrostatic image is formed directly on the final copy paper and does not have to be transferred. The papers used in the Electrofax process are coated with zinc oxide which acts as a photoconducting material. The finely divided zinc oxide is held on the paper by an insulating binder, such as resin. The coating also contains a combination of dyes that sensitize the zinc oxide to visible light.

In the printing process, the coated paper is first given a negative charge in the dark by corona discharge. It is then exposed to the image projected by a lens system. Light from the nonimage areas of the document causes the charge on the paper to be dissipated in the corresponding areas. This leaves an electrostatic pattern on the paper that duplicates the image of the original.

Either dry or liquid developer is then used to produce the visible image. In the dry method, the developer consists of a mixture of pigmented resin powder and iron particles which is applied to the paper by means of a magnetic brush. As this brush moves the paper, the positively charged resin powder adheres to the negatively charged areas of the paper, while the iron particles are retained on the magnet. The paper is then heated for a few seconds to fuse the resin powder to it.

Some advantages of the direct electrostatic process are that it:

- Can copy all colors.
- Makes excellent reproduction of printed matter, photographs, and large solid areas.
- Makes copies rapidly.
- Makes permanent copies.

The disadvantages include the following:

- Copies must be made on coated paper.
- Paper may be heavier than ordinary paper because of coating.
- Copies developed with liquid may smear for a short time after development.

Exercises (461):

1. What is the difference between the transfer and nontransfer systems?

462. Describe the dry silver process.

Dry Silver Process. There are a couple of types of dry silver materials on the market today. In this process the developer is imbedded in the film or paper. One of the outstanding features of this process is that it uses one-tenth to one-twentieth the amount of silver required in a regular silver process.

Most of the dry silver materials can be exposed on conventional-type printers. In one of the processes, heat is used to develop the film or paper once the material has been exposed. In this same process, heat causes the used and unused developer to evaporate and no fixation is required. The 3M Company makes a product that uses a thermal developing process.

The Eastman Kodak Company put out a second type of dry silver material that is first stabilized by heat, and then developed by exposing the material to high intensity tungsten radiation or to fluorescent lamps. The images produced by this process are also stable and no fixation is required.

Dry silver materials are very common in the field of micrographics. They are used in office copiers, microfilm copiers, and printers. As for processing, dry silver materials can be processed in sheets or in continuous rolls.

Exercises (462):

1. How are dry silver materials exposed?

2. Why is no fixation required for dry silver materials?

3. How are dry silver materials developed?

5-2. Diffusion Transfer

The subject of nonconventional image-forming systems would not be complete without a discussion of diffusion transfer systems. Let's now turn our attention to this technique.

463. Briefly describe the diffusion transfer processing technique.

Diffusion Transfer Principles. This is a processing technique by which the latent image is made visible by means of a developer that contains a silver halide solvent. As developer is also dissolving the unexposed silver halides. These unexposed halides are then transferred by a process of diffusion to the print material where they react with certain chemicals and form the positive image. Probably, the outstanding advantage of this type of system is that it affords rapid access to photographic information.

Many variations of diffusion transfer have been developed since the original concept evolved around the early 1940s. This early method was pioneered by Gevaert as a method of producing photographic copies on a paper support. The exposed silver halide material was first developed to a negative in a solution which contained a silver halide solvent. This material was placed into contact with another nonsensitized material which became the support for the transferred image. The second material contained a developer chemical that formed an image as the diffusion of the unexposed silver halides took place.

Another method of diffusion transfer brings the sensitized image-bearing layer into contact with the nonsensitized layer in the presence of the silver solvent developer. Thus, development of the negative and positive occurs concurrently.

A third method involves two layers on a single film: a light-sensitive layer coated on top of a nonsensitized layer, both adhering to a single support. After exposure, a two-solution development process takes place. First, the developer produces a negative image in the sensitized layer near the surface of the layer. The material is now placed in a transfer solution whereupon the unexposed halides diffuse and attach to the nonsensitized layer where the positive image is formed. The upper negative image-carrying emulsion is removed in a water bath, and the positive image remains attached to the base support material.

Exercises (463):

1. What is the diffusion transfer processing method?

2. How does the diffusion transfer processing method work?

464. Determine the probable cause of unsatisfactory conditions that might be encountered during the production of diffusion transfer products.

Polaroid. To produce the diffusion transfer positive in this system, the exposed negative is developed using a high-viscosity monobath solution. This solution is sandwiched between the exposed negative and the nonlight-sensitive positive transfer sheet. After a suitable developing time has elapsed, the two sheets are separated, and the positive image is contained in the transfer sheet.

In this method of diffusion transfer, three things are required, (1) a light-sensitive film (negative), (2) a high-viscosity developing solution, and (3) the specially treated nonlight-sensitive positive transfer sheet. Attached to the transfer sheet at intervals corresponding to the distance between one exposure and the next are a number of pods (one for each exposure) containing the high-viscosity developing solution. After each exposure, the film and transfer sheet are pulled from the exposure station through a pair of pressure rollers. These rollers break a pod of solution and squeeze together the transfer sheet and the film. The result is a sandwich with high-viscosity fluid between the layers. After about 10 to 15 seconds, the sandwich thus formed is peeled apart, and the transfer sheet contains the chemically formed positive image. The completed print is semidry, permanent, and requires no treatment except coating with a special chemical (contained in the print coater) which protects the film from scratches, discoloration, and eventual loss of detail.

Since Polaroid photographs are usable in many different activities, the material and the processing system have been expanded to provide a capability in a number of specialized areas. One innovation is 4- by 5-inch film holder which can be used with many press and view cameras. Once this holder is positioned in the camera, film packet after film packet can be inserted and exposed without removing the holder. Development takes place inside the packet, outside of the holder. A specially designed film packet contains the negative, the positive sheet, and the developing pod.

Much specialized equipment has been designed for the use of Polaroid film. One such item is the Perkin-Elmer Corporation's photomicrographic enlarger. This printer quickly produces 15x, 33x and 64x magnifications of selected portions of negative for quick photo interpretation. The optical system of the enlarger is almost the same as used in a microscope. Field of view is small and resolution is up to 635 lines/mm at the 64x magnification. Exposure is made by means of a special Polaroid back which uses Type 42 rollfilm or 46L or 146L for positive transparencies. Type 48 color film is also usable. A viewing screen is provided at a point just below the film holder. The image is displayed on the viewing screen by means of a swinging mirror. After the desired area is found, the exposure lever is operated, the swinging mirror moves out of position, and the image falls on the film.

Another use for the special Polaroid back is in its adaptability to the cathode-ray tubes of nonairborne radar indicators by means of the Type KS-12 still picture camera set. In this configuration the picture can be viewed in a minimum length of time without the usual long wait before conventional reproductions are available.

In addition to specially designed equipment, many special Polaroid emulsions are available. One such emulsion is Type 413, rollfilm (3¼ by 4¼ inch reproductions) which has infrared sensitivity. Development time is 15 seconds. Fast availability of the photograph is an asset in experimental and scientific photography. This emulsion is relatively stable and can be stored at ordinary room temperatures, although refrigeration in the original humidity-proof package is recommended. This is a high-speed, high-contrast material. Sensitivity to light extends from the visible region of the spectrum to beyond 900 nanometers in the infrared region, peaking at 840 nanometers.

Another special Polaroid rollfilm is Type 410, called Polascope. This emulsion provides extra sensitivity for data-recording situations and is specially adapted to oscilloscope recording. The film has an equivalent A.N.S.I. speed of 10,000 for middle gray scale tones. Such extreme sensitivity is especially desirable for photographic oscilloscope traces. With low-speed oscilloscope traces or stationary traces, use of this film enables a lower intensity of the cathode-ray tube and/or smaller lens apertures. Low scope intensity is desirable to produce photographic traces with maximum sharpness and absence of blooming (image spread). Additionally, faster shutter speeds help eliminate undesirable modulation and jitter. Some applications of this film in addition to CRT recording, are as follows:

- Photomicrography.
- Metallography.
- Ultra-high-speed photography using Kerr cells and other special shutters.
- Underwater photography.
- Astronomical Photography.

Exercises (464):

1. A Polaroid print is too dark. Is this the result of exposure or development? Explain your answer.

2. Are Polaroid prints that are too light caused by overexposure, or underexposure? Explain your answer.

3. List the three things required for the diffusion transfer method used for Polaroid production.

CHAPTER 6

Editing and Assembling

IN THE FIELD of high-altitude reconnaissance photography, original negatives are priceless. They give us a permanent record of a vast amount of detailed information within the view of the camera lens—information that is acquired only through careful planning and at great expense. Furthermore, the information the negatives contain may be such that it can never again be obtained. In the previous volume, we discussed film processing and emphasized processing original negatives. As a result of your work, you now have on hand original, one-of-a-kind films.

For various reasons, your roll of negatives can be studied and restudied. But whenever you study the negative roll, you must view it, and viewing requires handling and a risk of potential damage. Additionally, it is usual to disseminate information among various Air Force organizations. With only one roll of negatives, this is impossible. Therefore, the negative roll must be reproduced. Thus this volume concerns the printing of a second generation duplicate positive (DP), which we will refer to as "a dupe pos," and a second generation duplicate negative (DN), which we will refer to as "a dupe neg," from the original negative (ON). The dupe pos can then be used to reproduce any number of subsequent generation dupe positives or dupe negs, depending on the type of film used. The same holds true for the dupe neg.

You will find that printing is one of the primary tasks of the imagery production lab. Whether you are making a positive transparency or a duplicate negative from the original, it is imperative that any loss of information be held to an absolute minimum. The image must not be degraded. Printing is an exact science. Thus utmost control must be maintained so that little or no loss of image occurs.

6-1. Roll Film Breakdown

Naturally, the first step after processing is inspecting the material for physical defects. During this inspection, note and record on an inspection sheet all physical defects, camera malfunctions, an estimate of percent of fog, and a statement of the general quality of the original negative.

The defects you find should be checked with the results of the preinspection. For example, edge deckling caused by the processor would not have appeared during preinspection. In general, defects are listed during each step of the entire lab handling sequence, so that they can be traced to their source and eliminated. At this point the film is ready for another viewing, often referred to as the primary breakdown.

465. State the reason for primary breakdown and the purpose of leader and trailer segments.

Primary Breakdown. Primary breakdown of original negative serves one major purpose. That is, you breakdown the long roll into smaller rolls, each roll consisting of a single pass or other logical division. Each roll includes a leader and a trailer which furnishes identification information deemed necessary by your lab. Leader and trailer segments are spliced on in the usual manner. The mission log sheet should be annotated to identify your breakdown. Following this breakdown, it is necessary to add complete identification information to be printed over to the master positive.

During this task, you should view the film over a light table equipped with a splicer. Since original negative processing rolls are to be cut, it is advisable that two operators be present. "Two heads are better than one."

An editing table consolidates (into a compact work center) the accessories essential to rollfilm editing. Diffused fluorescent light is provided for the viewing of film. Adjustable masks restrict the illuminated area to a width more suitable for the size film being viewed. These masks also block flare light at the edges where it could interfere with your vision.

A splicing assembly mounted over the viewer includes a knife to square the ends of the selected film sections. A clamp holds the film ends in place as they are spliced with tape under heat and pressure.

Rewinds may be set to accept film spools in various widths. Many tables include a dual rewind assembly which is desirable in some operations. This motor driven unit includes under-the-table spindles that hold leader and trailer material. These accessory films are fed through a slot in the table top to the splicer in approximate register with the film to which they are spliced.

A motor-driven transport system moves the film in either direction at the tension and speed you select. Tension is adjustable to high or low. Any speed, from creep to maximum, can be obtained. A manual rewind version of this same table is also available, but it does not include leader and trailer storage. With the manual unit, you must control tension by hand-snubbing the feed roll.

Exercises (465):

What is the purpose of primary film breakdown?

1. Why is leader and trailer material spliced on each roll after primary breakdown?

2. How does an appropriate editing table enhance film editing?

466. State the reason for secondary breakdown and select the best solutions for given situations that might be encountered during roll-film breakdown.

Secondary Breakdown. After primary breakdown, the original negative is then evaluated by the densitometry section. During this evaluation, the original negative roll is tested for extreme differences in maximum densities and density ranges between frames. If such differences exist to the point that duplicating exposure or processing gamma must be changed during the reproduction step, the densitometry section recommends a second breakdown operation. The densitometry section adds a printing instruction sheet indicating the required breakdown points.

D/max and D/min information may indicate that a breakdown of the various rolls into more than one part is necessary. If so, cut the roll between the frame numbers as indicated. As appropriate, attach leader and trailer and include necessary identification information on the leader and trailer. Place the various sections in sequentially numbered film cans.

We recommend that a secondary breakdown sheet be made showing the following information (this sheet should accompany each roll):

- Roll number and camera position.
- Can number.
- Inclusive frame numbers.
- Total frames.
- Comments.

Write the roll breakdown and can numbers on the printing information sheet. Enter the following information on the can label:

- Mission number.
- Roll number and camera position.
- Can number.
- Inclusive frame numbers.
- Film type and copies required.
- Printing density.

Rolls are now ready for duplication. Note that all operations maintain a close check on identification. Make sure that you carefully verify the information that you enter on any form. Do not guess.

Exercises (466):

1. What is the purpose of secondary film breakdown?

2. Determine what action should be taken when the following situations are encountered during film breakdown:

   a. A roll that has long stretches of shadows produced by dense cloud cover.

   b. A roll that consists of sandy terrain at the head of roll and dense foliage beginning approximately halfway into the roll and extending throughout the remainder of the roll.

6-2. Removing Unwanted Footage

One of the subtasks of primary film breakdown is removing the unwanted material footage from the mission film. This section explains what unwanted footage is and how it is produced.

467. Identify areas of aerial rollfilm that are not considered a part of the mission film and explain why they should be deleted from the roll before printing.

Explanation of Unwanted Footage. The term "unwanted footage" is used to identify material that is not an actual part of the mission. To understand just what this means, let's trace the film from camera uploading, through mission recording, to camera downloading at the conclusion of the mission.

When the unexposed film is loaded into the camera magazine, several feet of it are used to attach to the takeup reel and to insure that the film is advancing and taking up properly. The magazine is then taken to the reconnaissance aircraft where it is positioned onto the camera. Here, the camera power supply is activated and several camera cycles are allowed to check out the camera operation. The film footage expended here is called ground clearance.

Once the aircraft becomes airborne, the pilot usually exposes several more feet of film before reaching the target area. This action serves two purposes. First, to doublecheck the operational capability of the camera and, second, to advance film footage that might have been accidentally fogged during camera uploading. This section of film is called air clearance. The pilot then proceeds to the target and records it. If two or more targets are to be photographed on the same flight, or if more than one pass must be made on any one target (such as prestrike and bomb damage assessment), the pilot might choose to expose a few more feet of film to separate one target or mission from the others.

When all targets have been recorded, the pilot returns to the base. Upon landing and parking the aircraft, the camera is again operated to insure that all valuable mission footage is on the takeup reel. This is to prevent accidental fogging of the film during downloading procedures.

Since so many extra exposures are made in the course of a mission, you can see that many feet of useless material might be contained on a roll of original negative material. To retain this unwanted footage would only extend the handling time of subsequent steps, expend more duplicating materials and chemicals, and consume additional manhours.

Exercises (467):

1. The following list of sequences might be found on a roll of aerial original negatives. Indicate which sequences might be considered wastage.

   a. Completely fogged film.

   b. A sequence of closeup flight line exposures.

   c. A sequence of cloud cover.

   d. A sequence containing a railhead.

   e. A sequence of dense foliage.

   f. Several frames of a missile site.

   g. A sequence of closeup flight line exposures.

   h. Completely fogged film.

2. Why are ground and air clearing frames deleted from the roll during rollfilm breakdown?

468. Indicate the disposition of air and ground clearance footage under given situations.

Selecting What Film To Remove. During rollfilm breakdown, you must exercise care in selecting the areas of the original negative (ON) roll to be removed. In some situations, all frames between the end of the first air clearance and the beginning of the postflight ground clearance are retained. In other cases, the original negative roll might be separated according to targets. This CDC cannot dictate which method to use. Instead, the method is preestablished for each operating unit and mission.

Aerial reconnaissance film is not the only photography from which unwanted footage must be removed. This also occurs in motion picture work. However, the removal of material from motion picture footage is not as critical as it is in aerial reconnaissance work. One frame of aerial reconnaissance ON can contain 100 percent of the desired information that might be impossible to replace. Very few, if any, motion picture scenes have ever been lost because of losing one frame from the beginning or end of the sequence.

Exercises (468):

1. How do you decide which of the methods to use in selecting the areas of the ON to remove?

2. Why must you be more cautious when removing frames from aerial reconnaissance ON than when removing frames from motion picture frames?

6-3. Attaching Head and Tail Leader Material

During rollfilm breakdown, leader material is usually attached to each end of the film after the clearing material has been removed. Now, let's look at the procedures for and requirements of this task, keeping in mind that local practices and governing directives may change these procedures.

469. Specify the methods and state the purposes for attaching friskets or leader strips onto rollfilm.

Attaching the Leader Strips. Leader strips or friskets are attached to rollfilm for two primary reasons. First, for both aerial reconnaissance and motion picture materials, when properly annotated, the friskets provide pertinent identification information that is easily accessible. Furthermore, for motion picture materials, it is the *only* source of this identification information. Second, when the original material is to be printed on a continuous printer, additional material other then mission footage is required to thread the printer.

In all cases, strips are attached to both the head and tail of each roll. Even though the information that is annotated on both the head and tail frisket is the same, there are minor variations in the placement of this information on the frisket which prevents them from being interchangeable. The information which is annotated on the motion picture leader and trailer varies considerably, and again they are not interchangeable.

When attaching friskets to the original negatives, the negatives must be wound so that the first exposure made is on the outside of the roll, emulsion down. This roll should then be positioned on the left-hand side of a splicer/rewinder or a viewing table that has a motor rewind.

The head frisket is then placed so that the imprinted information can be easily read. Both the film and frisket ends are cut squarely and joined, usually with "Mylar" type tape. (In some cases, and usually in all situations concerning motion picture materials, the film cement or heat splicing methods are used.) The film is then wound to the right side and the tail frisket attached in a similar manner. When the friskets are properly attached, the imprinted information should be near the mission footage with a substantial quantity of clear leader material on the extreme ends of the combined roll.

Exercises (469):

1. What method is used to attach leader strips to motion picture material?

2. What method is used to attach friskets to aerial reconnaissance material?

3. What are the purposes for attaching frisket or leader materials to rollfilm?

470. Given a list of tasks that were accomplished improperly, explain the results on the end photographic product.

Precautions in Attaching Leader Strips. As with any step in the photographic process, you must exercise care in attaching frisket or leader material to mission film. If you are not careful and local OOIs are not precisely followed, physical damage might result and the entire roll might be lost.

The first requirement, of course, is that the splice be made correctly. Unlike previously discussed splices, these do not come in contact with solutions and need not be durable in the wet state. However, since most original materials are subjected to many stresses and strains during the printing stage, they must be durable in the dry state. Furthermore, the leader materials must be spliced squarely to the mission materials. Otherwise, the material will mistrack during high-speed printing.

Other mishaps are also possible. You can imagine the confusion that would result if the head frisket were spliced on the tail end of a roll of vertical aerial photographs, and each frame titled and numbered sequentially based on the placement of this frisket. Such incidents are inexcusable and you must avoid them.

Exercises (470):

1. Determine the probable result if the following situation occur.

   a. The head frisket is not spliced squarely to the mission film, and the film is duplicated.

   b. The head frisket is spliced onto the tail of a roll of vertical aerial photographs.

6-4. Annotating Head and Tail Friskets

Once the friskets are attached to the mission film, they must be annotated with the appropriate information. This section deals with annotation of both aerial and motion picture film.

471. Identify the information that is placed on head and tail friskets, the leader strip, and the trailer.

Frisket Entry Information. The minimum entries made on the head and tail friskets of aerial reconnaissance film are established in Defense Intelligence Agency (DIA) Manual 55–5, *Aerial Photography Airborne Sensor Imagery (Forwarding, Tilting, and Plotting)*. As prescribed by this manual, the following information must be included:

- Camera position (depression angle).
- Taking unit.
- Sortie/mission number.
- Date(followed by a double hyphen [=]).
- Focal length and enlargement coefficient.
- Project name and/or number.
- Security classification and downgrading group number.
- Release instructions, if applicable.

If space on the friskets permits, the following information is also included:

- Service.
- Time group and zone letter.
- Altitude.
- Kind of photography or imagery.
- Geographic coordinates.
- Descriptive title (if applicable).
- Sensor type or model identification.

Leader strips attached to original motion picture materials must also be annotated. The following typical items of information are included on the leader:

- Project number.
- Work order number.
- Roll number.
- Security classification.
- End identification (head).
- Type of film.
- Production organization.
- Production date.
- Footage or number of frames.

Your organization may or may not include all of these items. To provide rapid identification, it is often advisable to place the project number and security classification at the very beginning of the roll.

A trailer is approximately 6 feet in length and is composed of opaque film with transparent letters, numerals, or perforations. The following items of information are often included on a trailer:

- Project number.
- Tail identification.
- Security classification.
- Footage or number of frames (especially necessary for classified rolls).

Exercises (471):

1. Place a check mark by each of the following items that must be included on head and tail friskets of aerial reconnaissance film.

____ a. Geographical coordinates.
____ b. Taking unit.
____ c. Date.
____ d. Time group and zone letter.
____ e. Camera position.
____ f. Altitude.

2. What items of information should be included on both the leader strip and the trailer?

472. Associate improperly annotated head and tail friskets.

Effects of Improper Frisket Annotation. In many instances, and especially in aerial reconnaissance, the information entered on the friskets is used during subsequent handling steps. As an example, when setting up the type block for titling aerial roll film, some of the needed information, such as release or dissemination instructions, might not be indicated on the work order. If this is the case, then the only source of this information is the annotated frisket. The same holds true for other types of information. If the frisket is the sole source of information needed for titling, and if the frisket annotations are incorrect, then several hours might be wasted in hand cleaning the film because of the erroneous titling, and retitling it with the correct information. Actually, no major harm has been done by this, but if the condition is not found and corrected within the originating organization, it can lead to irreversible damage further up the line.

An example of this might be erroneous geographic coordinates on a roll containing photographs of a missile site. If a bombing mission is planned around this information, and the geographic coordinates are off by as little as 1 minute, the target will be missed by approximately 1 mile. Furthermore, the bomber crew may be exposed to unnecessary danger because of this wrong information, and the possibility of being shot down by a missile is greatly increased.

Exercises (472):

1. Column A below contains a list of improperly annotated frisket information for aerial film. Match each item with at least one situation from column B that might result because of this incorrect information. Column B items may be used more than once or not at all.

Column A	*Column B*
____ (1) Security classification wrong.	a. Incorrect photo scale.
____ (2) Wrong altitude.	b. Incorrect target size.
____ (3) Wrong focal length.	c. Incorrect location of targets.
	d. Improper handling.
	e. Additional handling time.

6-5. Assembling Rolls for Printing

The final task to be achieved during film editing is assembling like rolls of film for printing. There are many advantages in doing this task. In this section, we will discuss the requirements for successful completion of this task, as well as some of the advantages derived.

473. State the purpose and the advantages and disadvantages of assembling rolls for printing.

Advantages and Disadvantages of Roll Assembly. Many tasks associated with wide and narrow films are done for the same reasons. However, assembling is not. Because the reasons for assembling them are different, motion picture and aerial films must be considered separately.

Aerial reconnaissance films. The main reason for assembling aerial rollfilm for printing is to facilitate the duplicating cycle. However, since the original negative roll usually cannot be cut, this action is restricted to the second and subsequent generations.

Many different exposing conditions are encountered in aerial work. A typical aerial mission might include all of the extremes from sandy or snowy high reflectance terrains to dense jungle foliage. There might be areas of extremely high subject contrast in one portion of the roll, and extremely low subject contrast in the remainder of the roll. Mission recording could be started in bright sunlight, and ended under dense cloud cover. In most cases, mission film contains two or more of these exposing conditions.

Since it is the responsibility of imagery production processing personnel to produce the best possible product, variations in exposure or processing or both might be required when duplicating black-and-white film roll. If the change is related strictly to processing, then two or more processing rolls are required. However, if the change is required because of density differences produced during exposure of the original negative, then two alternatives are possible.

The first alternative is split-printing. In this system, the dupe pos is evaluated densitometrically and sections are identified according to duplicating exposure requirements. The dupe pos is then threaded on the printer. The first exposure is set, the film is printed to the first exposure change, and the printer is stopped. A few feet of the dupe pos is rewound, the new exposure set, and more film is printed. This process continues until the entire roll is printed. As you can see, much time is expended rewinding the dupe pos, resetting the exposure, and starting and stopping the printer. Furthermore, many feet of duplicate waste are produced.

The second alternative is by far the more economical when several different rolls, each containing different density levels, are to be duplicated. Again, the dupe positives (not the ON) are evaluated densitometrically. The sections of the rolls requiring the same duplicating exposure and duplicating process gamma are removed and spliced together to make one printing roll. In this way, the printing exposure may be set and the printer operated until the entire roll has been duplicated. While this method necessitates greater exactness in record keeping, the savings of time and material are substantial.

Exercises (473):

1. What purpose is served by assembling aerial film for printing?

2. What is the primary advantage of assembling aerial film for printing?

3. What is the disadvantage of assembling serial film for printing?

4. If an exposure change is required during aerial rollfilm printing, what alternatives do the operator have?

CHAPTER 7

Titling and Cleaning

OTHER TASKS that must be done before duplicating original camera film are cleaning and titling. This chapter is restricted to a discussion of these tasks.

In Chapter 4 of this volume, we discussed the first postprocessing handling step. As you will recall, the original material is handled quite extensively during editing and assembling. Because the original material is subjected to this treatment, there will most likely be an accumulation of dust, dirt, lint, etc, as well as some fingerprints on this material. Even if none of these are visible, it would be foolish to assume that they do not exist. Therefore, each roll of material must be cleaned just prior to printing.

The second task that must be accomplished prior to cleaning aerial rollfilm is titling. During titling, the film is again handled. Also, the titling tape pigment flakes off, leaving small particles of the pigment on the film. Since just one of these flakes can obliterate an entire target, they too must be removed during the cleaning process.

7-1. Titler Startup Procedures

Certain startup tasks must be performed prior to operating a titling machine. Some of these tasks are performed while other titler operating functions are being certified. Each type of titler is different and will have its own tasks that must be performed. As an example, we will start by talking about the tasks required for the dual-head titler.

474. List tasks to perform during startup of the dual-head titler and specify duration of heater controls' maximum setting period.

Dual-Head Titler. The dual-head titler is a pneumatic electrical device, designed to apply coded title information and sequential frame numbers in the clear unexposed border of processed rollfilm. All standard film widths between 70 mm and 9½ inches can be titled. Indexing counters supplied with titler can print up to 9 digits in sequential or repetitive order. Although the machine is equipped with two titling heads, it is possible to use only one head by turning off the controls to the other.

To prepare the titler for operation, the main power switch is turned to the ON position. After the power is turned on, the following tasks must be completed before titling will occur:

1. Set No. 1 counter heater and No. 1 type heater controls to their maximum settings.
2. Set No. 2 counter heater and No. 2 type heater controls to their maximum settings.
3. Let the heater controls remain at their maximum settings for 10 minutes.
4. Return the knobs to their recommended (counter heaters to 30 and type heaters to 48) settings to allow heating elements to heat the counter and lead type to the proper temperature.
5. Adjust incoming air pressure with the machine pressure control regulators listed below, until the pressure recommended is attained.
   - *a.* No. 1 counter pad (10 psig).
   - *b.* No. 1 type pad (15 psig).
   - *c.* No. 2 counter pad (10 psig).
   - *d.* No. 2 type pad (15 psig).
   - *e.* Counter air (30 psig).
   - *f.* Open counter sequencing air valves No. 1 and No. 2.

The titler will be ready for operation after the counter and lead type reach the proper temperature.

Exercises (474):

1. List the tasks that must be performed during startup of the dual-head titler.

2. What is the duration of the period the heater controls are to remain at their maximum setting?

7-2. Aerial Rollfilm Titling

Several titler operating functions must be certified before titling film. One of these might be the heating capability of the head. While not absolutely required during each titler startup, the titler head should be certified periodically with a pyrometer.

475. State the purpose of certifying the titler head temperature and explain the result that can be expected when certification is not satisfactory.

Certifying the Titler Head Temperature. The ability to imprint identification information on aerial rollfilm is made possible by two conditions. These conditions are heat and pressure. First, the titling type must be heated sufficiently to imprint the titling tape pigment onto the film when sufficient pressure is applied. Secondly, the combination of heat and pressure must be such that the imprint is made without embossing the film or causing the titling tape pigment to flow.

You should understand that too little heat results in the pigment not separating cleanly from the titling tape base. Too much heat results in the clean separation of the pigment from the tape base, but it flows after being transferred to the film.

Since heat is supplied by heating elements within the titling head, it is possible to maintain a correlation between the actual heat supplied by these elements and the heat indicated by the temperature indicator. This method of correlation is made possible by using a pyrometer.

A pyrometer is an instrument for measuring temperatures that are beyond the temperature range of mercury thermometers. Usually, the instrument measures the heating potential by determining the change of electrical resistance of, in this case, the heating elements of the titling head. There are other types of pyrometers, of course, and any of these may be found in imagery production laboratories. However, regardless of type, they all serve the same purpose, and that is to certify that the titling head is within the temperature range as indicated by the titler temperature indicator.

Exercises (475):

1. What purpose does a pyrometer serve?

2. If the titler is not certified with a pyrometer, what is likely to result if the heating element becomes:

   a. Too hot?

   b. Too cold?

3. What factor will result in the film becoming embossed?

476. Specify measures needed to correct titling defects in a given list.

Making Titler Head Heating Adjustments. Certifying the titler with a pyrometer has confirmed that the titler head heating elements can produce the desired heating range necessary for proper transfer. Now, the heating controls on the titler must be set according to the type of material being titled and in some cases, the condition of the titling tape.

One of the most widely used aerial rollfilm titlers is the Dual-Head Title, Model 1-A as shown in figure 7-1. For this reason, we will restrict our discussion in this, and subsequent sections, to the titler.

The lead type and counter must be heated and have proper pressure applied to transfer the pigment to the edge of the film properly. To heat the counters to the proper operating temperature, two heating elements are installed in each counter. (The dual-head titler has two titling heads which may be operated individually, or together). The temperature of these heating elements is controlled individually by the Variac control knobs.

To heat the lead type, a 240-watt heating element is installed in each of the two blocks. The temperature of these heating elements is controlled by the Variac controls knob labeled "No. 1 TYPE HEATER" and "No. 2 TYPE HEATER." The No. 1 TYPE HEATER is the temperature control knob for the type in printing head 1 (left-hand head). During operation, adjustment to these Variac controls depends upon characteristics of the material to be titled. If the temperature of these heating elements is too high, the transfer medium will flow, and if the temperature is too low, improper or illegible transfer will result. (CAUTION: *Both the counter and type block are hot, and contact with either could cause a burn.*)

Exercises (476):

1. What action should be taken when the pigment imprint on film appears to be "fuzzy?"

2. If the lines which form the titled letters or numbers are not continuous, what action should be taken?

3. What is likely to happen when the titler is certified on the film 0.010 mils thick, and then film 0.005 mils thick is titled? Can this situation be corrected by readjusting the temperature of the head?

477. Define pneumatic and explain how pneumatic devices are used on titlers.

Pneumatic Adjustments. As previously stated, heat and pressure are required for titling operations. Since the previous paragraphs were related to heat, let's now take a look at the other factor—pressure.

Any device or system that operates from pressure created by compressed air or, in rare cases, other gases is commonly termed "a pneumatic device." The titling heads on most aerial rollfilm titlers are no exception. The downward thrust, or stamping action, needed to imprint the identification information onto the film is provided by air pressure. While some titlers use tanks of compressed air, others contain an air compressor, and both of these provide the pressures needed to operate the titling head. As with any system that relies upon air pressure, the amount of air pressure available to the system determines the speed at

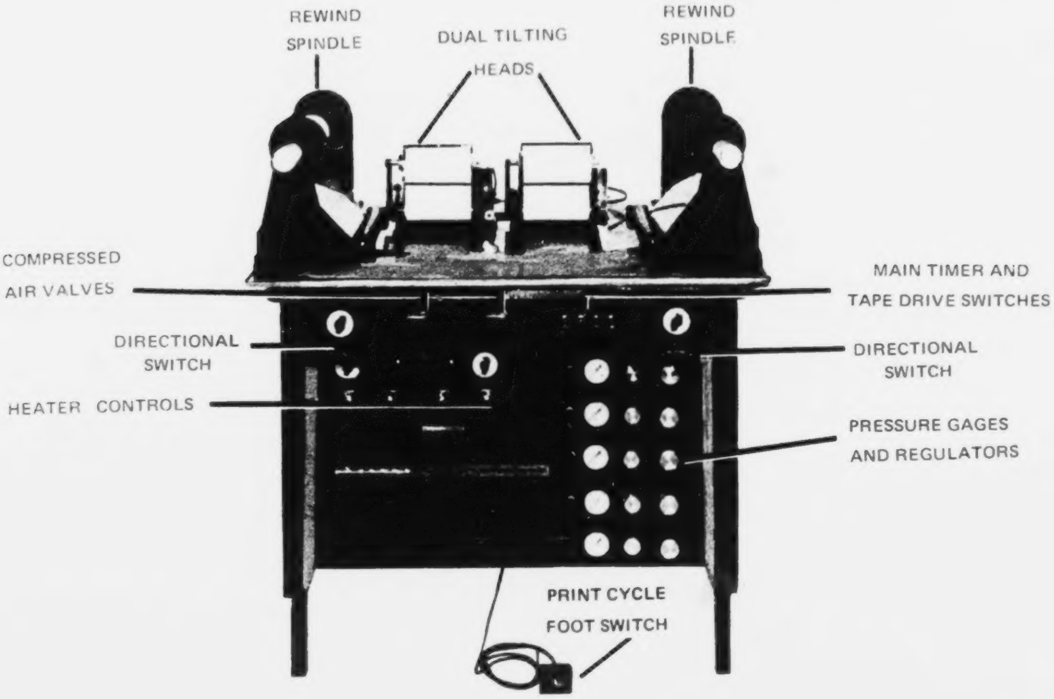

REWIND SPINDLE
DUAL TILTING HEADS
REWIND SPINDLE
COMPRESSED AIR VALVES
MAIN TIMER AND TAPE DRIVE SWITCHES
DIRECTIONAL SWITCH
DIRECTIONAL SWITCH
HEATER CONTROLS
PRESSURE GAGES AND REGULATORS
PRINT CYCLE FOOT SWITCH

Figure 7-1. Dual-Head Titler, Model 1A.

which it operates. Naturally, in the case of titling heads, this speed is directly related to the pressure applied to the titling tape and, subsequently, to the film during titling.

Exercises (477):

1. What does the term "pneumatic" mean?

2. What part of the titler is considered a pneumatic device?

3. What titling function is influenced by pneumatic action? Explain.

478. Given situations that might result in improper titling, determine and explain how pneumatic adjustments might be responsible.

Pneumatic Adjustment Causes of Improper Titling. To obtain the proper printing pressure on the dual-head titler, adjustments can be made to change the readings on the gauges labeled "No. 1 COUNTER PAD, "No. 1 TYPE PAD," "No. 2 COUNTER PAD" and "No. 2 TYPE PAD." Readings on these gauges are changed by the two control knobs to the right of each gauge. The extreme right control knob should be fully operational for each gauge and then the proper pressure achieved by turning the control knob nearest the gauge counterclockwise to decrease the gauge reading or clockwise to increase it. Proper pressure is achieved when the film is not embossed and the title is clear and legible. Each counter stamp pad and each led type stamp pad has its own pressure gauge so that the pressure for each counter or lead type stamp pad can be adjusted individually.

The pressure gauge labeled "COUNTER AIR" and the control knobs to the right of this gauge are used to control the pneumatic system for indexing the counters.

If the pressure on the counter pad and type pad gauges is too high, it causes embossing of the film. If the pressure is too low, it causes light, or possibly illegible titles and reference numbers. If the pressure on the counter air gauge is too low, it causes improper indexing of the counters.

Exercises (478):

1. Explain what pneumatic adjustment should be made to correct the following undesirable titling situations:

   a. Several consecutively titled frames contain the same frame number.

b. Embossing where the film has been titled.

c. Illegible identification information.

479. Cite the cause of specific titling defects which occur when certain recommended air pressure settings are used.

Air Pressure Settings. Since the operation of pneumatic systems is directly related to the available air pressure, some method of controlling the titler air pressure must be available. This method is the use of air pressure valves.

If the quality of the titled information transferred to the film is to remain constant, a constant air pressure is required. This is insured by an air pressure greater than that actually being supplied by the air compressor or bottled compressed air. Valves are then placed in the air supply lines. In this way, the input air pressure can be decreased to some level below maximum before it becomes available to the pneumatic devices. With this system, even abrupt changes in the air pressure supply generally are not sufficient to degrade the quality of the titling.

For the dual-head titler, a constant air supply of 40 psi should be available for operation of the pneumatic portion of the machine. As previously stated, the air supply is then reduced by the pressure regulating valves to the proper operating pressure. It is recommended that this air be clean and dry. A compressor capable of delivering 3 cubic feet of air 40–50 psi is suitable as the source of compressed air.

Exercises (479):

1. A dual-head titler is being used to title film. Both heads are operating, with film travel being from left to right. The recommended air pressures for the type pads are: No. 1 – 15 psi, and No. 2 – 18 psi. The recommended air pressures for the counter pads are: No. 1 – 12 psi, and No. 1 – 10 psi. Using this information and the discussions in Objective segments 477 and 478, determine the cause of the following titling discrepancies:

   a. Embossing for even numbered frames.

   b. Odd numbers are repeated on several frames through the roll.

   c. Illegible information transfer on odd numbered frames.

480. Determine the results of an improperly performed preoperational task on titled film.

Counter Sequencing. Before you operate the titler there are a number of other procedures you must go through. One of these is to insure correct counter sequencing.

Each negative of the original roll of aerial film is numbered sequentially, usually beginning with number 1 for the first frame. This necessitates that before a roll is titled, the counter must be reset. These indexing counters are constructed of a somewhat soft metal that is easily damaged if handled improperly.

When resetting the counter, the first step is to remove the printing head to the raised position. The counters in the printing head is then set to the proper digit or digits for the first frame of the film to be numbered. To set these counters, rotate each row of numbers, using a wooden stick, until the proper digit is reached. If both heads are to be used, one counter must be set up to imprint even numbers (2, 4, 6, etc.), while the other counter is set up to imprint the odd numbers (1, 3, 5, etc.).

The importance of using a wooden stick for this operation should be evident. The wood is usually softer than the metal used to make the counter wheels. Therefore, if any damage is done to either. It is usually done to the wooden stick and not to the counter wheels.

Exercises (480):

1. What is likely to happen if a metal object is used to reset the counter wheels?

2. What will happen during titling if both counters are reset to the same number?

481. Cite probable results if given situations occurred while the titler is being threaded.

Threading the Titling Tape. After the counter has been reset, the next step is to provide tape for the titling operation. This is done by either threading the titler with new titling tape, or by advancing the tape already on the machine so that fresh unused tape is available for titling.

Kodak "Brownsville" tape is used as the transfer medium and is fed between the film and the lead type and counter.

When threading the dual-head titler with titling tape, place the tape on the printing head supply spindle so that the coating on the tape is next to the film when the printing head is lowered to the printing or titling position. Thread the tape over the guide roller, in front of the upper phenolic roller and the rubber covered drive roller, behind the lower phenolic roller, and into the exit slot so that a few inches of tape extend into the exit chute.

To prevent a flowing imprint of characters from heat softened tape, when starting a titling operation, move the tape advance switch to the ON position until unmarked tape is under the counter and lead tape.

If the tape does not advance sufficiently to prevent superimposition of characters on the tape, move the stops on the cam located at the extreme left of the timing unit slightly farther apart. Select a position to permit advancing only sufficient tape to prevent superimposition, being careful to prevent tape waste. To gain access to the timing unit, turn the knob below the Variac control knobs counterclockwise and open the hinged door.

Exercises (481):

1. What effect will improper advancing of the titling tape have on titled information?

2. What will result if the heat from the titling head is allowed to soften the titling tape pigment?

482. Cite the results if given situations occurred during typesetting.

Setting the Type. Probably the most confusing task related to titling is the setting of the type. While this task seems simple at first, it becomes rather complicated when it is actually being done. Furthermore, extreme care must be exercised when setting the type, for reversed characters can appear as being correct, while in reality, they are upside down (as an example, the numbers 6 and 9).

Typesetting principles. Look at any two printed lines on this page. What you see is a series of letters that form words. Furthermore, when these words are read from left to right, and from top to bottom, they form sentences. Now, visualize picking up two of these lines between your thumbs and index fingers and turning them upside down. What do you have? You have letters that are upside down. Furthermore, if we use as an example the first two lines in this paragraph, the word typesetting, in addition to being upside down, is located on the lower left-hand corner. The words which follow are again from left to right. However, the second line in the sentence is found above the first. This position, after the 180° turn, is the correct orientation at this point: The type holder must be positioned so that its handle is to your right as you face it. Otherwise, the transferred information on the film will read from right to left.

Exercises (482):

1. Type is set in a holder that is turned so that its handle is to your left. What direction will the imprinted information read?

2. Mission number 666 is set in the type holder so that these characters read 666. Upon transfer to the film, what number will be imprinted?

483. Determine the probable results of hypothetical situations that might occur during type setting and inserting the type holder into the titler.

Positioning of Type Holder in Titler. Now that the procedure for setting up the type holder has been discussed, let's see how to check the type for correct setting and the procedures for positioning the type holder in the titler.

To set up the proper title in the type block, remove the type block from the printing head. Then loosen the end screw in the type block and insert the segments of lead type in the block. To proofread the title, place the block in front of a mirror for normal orientation. Press each segment of type until it seats at the bottom and then hold all type segments in this position by tightening the end screw of the block. Then insert the block in the printing head and fasten it in place with the retaining screws.

When the type holder has been positioned in the titler heads of the dual-head titler, turn the main switch to the ON position. Then, set the No. 1 counter heater and No. 1 type heater Variac control knobs at their maximum setting for 10 minutes. After this 10-minute period, return these knobs to the predetermined setting to allow heating elements to heat the counter and the lead type to the proper temperatures. Reset the Variac control knobs lower (about 40) on the dial until tests made with a piece of scape film show satisfactory results.

Adjust the incoming air pressure with the machine pressure control regulators so that the gauge labeled No. 1 COUNTER PAD reads 10 psi and the gauge labeled COUNTER SEQUENCING AIR No. 1 and close the valve labeled COUNTER SEQUENCING AIR No. 2 if only one head is to be used. If No. 2 head is also being used, set it up the same way that you did No. 1.

Exercises (483):

1. Some of the characters are not level in newly set type. What will be the results if this holder is used without leveling the type?

2. After properly setting the type, the end screw of the type holder is turned so that it is extremely tight. What will probably result from this action?

3. After inserting the type holder into the head, the counter and type heater controls are not turned to their maximum control. What will be the result of this action?

4. The imprinted information on consecutive negatives becomes progressively farther away from the frame numbers. What task was performed incorrectly?

484. From a list of titling operating procedures, determine which procedures are wrong and state why.

Titling Operations. After all the previous tasks have been performed, you are ready to title the film.

Dual-head titler operating procedures. Before you begin titling mission film, adjust the pressure and heat while printing on scrap film. If possible, the scrap film should be of the same material as that to be titled.

After the machine has been set up for operation, turn the timer switch to the ON position, using either one or both printing heads.

If the film to be titled is on the left-hand spindle and is fed from the top of the spool, turn the film direction toggle switch below the supply spindle (left-hand spindle) to L to apply reverse torque to the supply roll to keep tension on the film during the titling operation. Turn the film direction toggle switch below the takeup spindle (right-hand spindle) to R to apply forward torque for windup of the titled film.

If the film to be titled is on the right-hand spindle and fed off the top of the spool, turn the film direction toggle switch below the takeup spindle (left-hand spindle) to L to apply forward torque for windup of the titled film.

In some titling operations, it is necessary to unwind the film from the bottom of the supply roll and wind the titled film onto the bottom of the takeup roll.

When unwinding from the bottom of the supply of the left spindle, turn the film direction toggle switch under the supply spindle to R to apply reverse torque to the supply roll to keep tension on the film during the titling operation. Turn the film direction toggle switch under the takeup spool to L to apply forward torque for windup of the titled film.

During titling, you must stop the film movement by applying pressure with a gloved hand to the large knob on the supply spindle. The frame to a title should be stopped directly under the printing head or heads, or as called for by the titling requirements. These requirements also determine whether one or both titling heads will be used, the method of using the titling heads, and the manner in which the titling is placed on the film.

After stopping the film movement, depress and release the foot switch to operate the timing unit which allows air to go to the lower cylinders on each printing head.

NOTE: The timing unit is preset at the factory and the set of cams should not be changed except for the cam on the extreme left which controls the tape advance.

Application of air to these cylinders raises the rubber-covered stamp pads to press against the counter and lead type. The pads are automatically held against the counter and lead type for the time limit set in the timing mechanism and then lowered to the rest position. After the stamp pads are lowered, the tape is advanced automatically and the counter is indexed to the next digit.

Exercises (484):

From the following list of titler operating procedures, determine which procedures were done incorrectly and explain why they were.

1. The pressure and heat adjustments were made using scrap duplicating film.

2. The film is supplied from the right-hand side and is fed from the bottom of the roll. In order to advance the film,

   a. The film direction toggle switch under the supply spindle is turned to R.

   b. The film direction toggle switch under the takeup spindle is turned to L.

485. Determine and explain the cause of improperly titled film from a list of examples.

Titler characteristics. A titling cycle on the dual-head titler takes about 4.5 seconds to complete. If you fail to release the foot switch as soon as you hear the lower cylinders advance, the entire cycle repeats.

As previously discussed, if the tape does not advance sufficiently to prevent superimposition of characters on the tape, move the stops on the cam farther apart. Permit sufficient tape to advance to prevent superimposition, but not enough to create waste.

When shutting the machine down, move the printing heads to the raised position to keep from forming a flat spot on the rubber-covered tape drive roller. Turn off both the main switch and the air supply. If the machine is to be idle for even a short period of time, it is good practice to turn the timer switch off. If the titling data contains classified data, be sure that you remove and jumble the characters contained in the type block after titling is completed.

Exercises (485):

1. During titling operations, only the bottom row of information from a two-row type block is being imprinted on the film. What is wrong?

2. What could cause two complete sets of information on the same negative?

3. Negatives of a roll of film titled on the dual-head titler are numbered 1, 1, 3, 3, 5, 5, etc. What is the reason for this? (Refer to Objective segment 480)

486. Explain the operation of the Tacoma film titler.

Tacoma Film Titler.

The Tacoma film titler consists of three main units; a control console, a feed adapter, and a mating table. The

Tacoma is attached, using an appropriate adapter, to the feed end of the Versamat processor. The titling data is exposed by a light-emitting diode (LED) array. The title format consists of .090 inch characters in four-digit sequence characters. The four-digit sequence number can be exposed in either ascending or descending order. The index mark, a plus sign, immediately follows the sequence number in all exposures. It serves as a datum for a coordinate indicator, which is used to locate specific areas in processed imagery.

Control Console. The Tacoma titler control consists of a keyboard, illuminated displays for both sequence number and desired titling data, plus controls for title spacing, exposure, and orientation. It houses a solid-state electronics package and associated power supplies. The keyboard is used to enter the sequence number and title information into memory bank. As the characters are entered they are displayed for an accuracy check. Individual characters can be removed and corrected without erasing the complete entry. Spacing between titles can be adjusted from 4.0 to 99.9 inches (the distance from one index mark to the next). This range can accommodate different camera formats. The title can also be made right-reading for even, odd, and nonmirrored camera systems, and for heads- or tails-out film processing. Since these titles are exposing prior to processing, they are not frame oriented, but the title spacing can be adjusted so that each frame will have at least one sequence number.

Feed Adapter. The Tacoma titler feed adapter consists of the LED array, and controls for focusing and positioning the title. The LED array exposes alphanumeric characters in a single line along one edge of the film in a dot matrix pattern. The title is developed into a photographic image as the film passes through the processing machine. Title position, relative to the film edge, is controlled by an internal coarse adjustment.

An external adjustment is used if fine corrections for precise title positioning are required. The feed adapter can be left on line for both titling and nontitle processing. In a multiprocessor operation, an adapter can be attached to each processing machine and left in place, allowing the rotation of the control console between the processors.

Mating Cable. The mating cable mates the control console with the feed adapter. The 20-foot cable permits locating the control console on any convenient surface near the titling operation. A battery backup prevents loss of titling data and sequence number during short power failure (1 to 2 minutes).

CAUTION: Do not unplug machine without turning main power switch OFF or the battery backup unit will come on and the batteries will discharge.

The Tacoma continuous film titler can accommodate all transport speeds required for color film and most black-and-white processing cycles on Kodak Versamat type processors. The Tacoma is an all-around asset to the reconnaissance lab, eliminating post-process titling operation, requiring no expendable supplies, and providing a titled image that is photographic.

Exercises (486):

1. How is the titler positioned onto the processor?

2. What happens if the titler suffers a loss of power?

3. Why is the Tacoma titler so valuable to a processing operation?

4. Explain the function of the LED array.

7-3. Film Cleaners

After aerial rollfilm has been titled and before it is printed, it must be cleaned. Most aerial rollfilm cleaners used by the Air Force employ "tacky" rollers to remove the foreign particles from the film. One such unit is the Tacky Roller Film Cleaner.

487. Identify the purpose, capacity, and function of the Tacky Roller Film Cleaner.

Film Cleaner Functions. This film cleaner is a device to remove dust and lint from aerial rollfilm in widths of 70 mm to 9½ inches and up to 1,000 feet in length. In addition to cleaning film, the unit also contains a static eliminator device which removes the static charges. This static charge elimination reduces further collections of dust and dirt.

The cleaner shown in figure 7-2 is manufactured by the Houston Fearless Corporation and is designated as Model TR-127. Refer to this figure when reading the following text segments related to the Tacky Roller Film Cleaner.

Exercises (487):

1. What is the purpose of the Tacky Roller Film Cleaner?

2. What size film will the Tacky Roller Film Cleaner handle?

3. How does the Tacky Roller Film Cleaner prevent reaccumulations of dust on the cleaned film?

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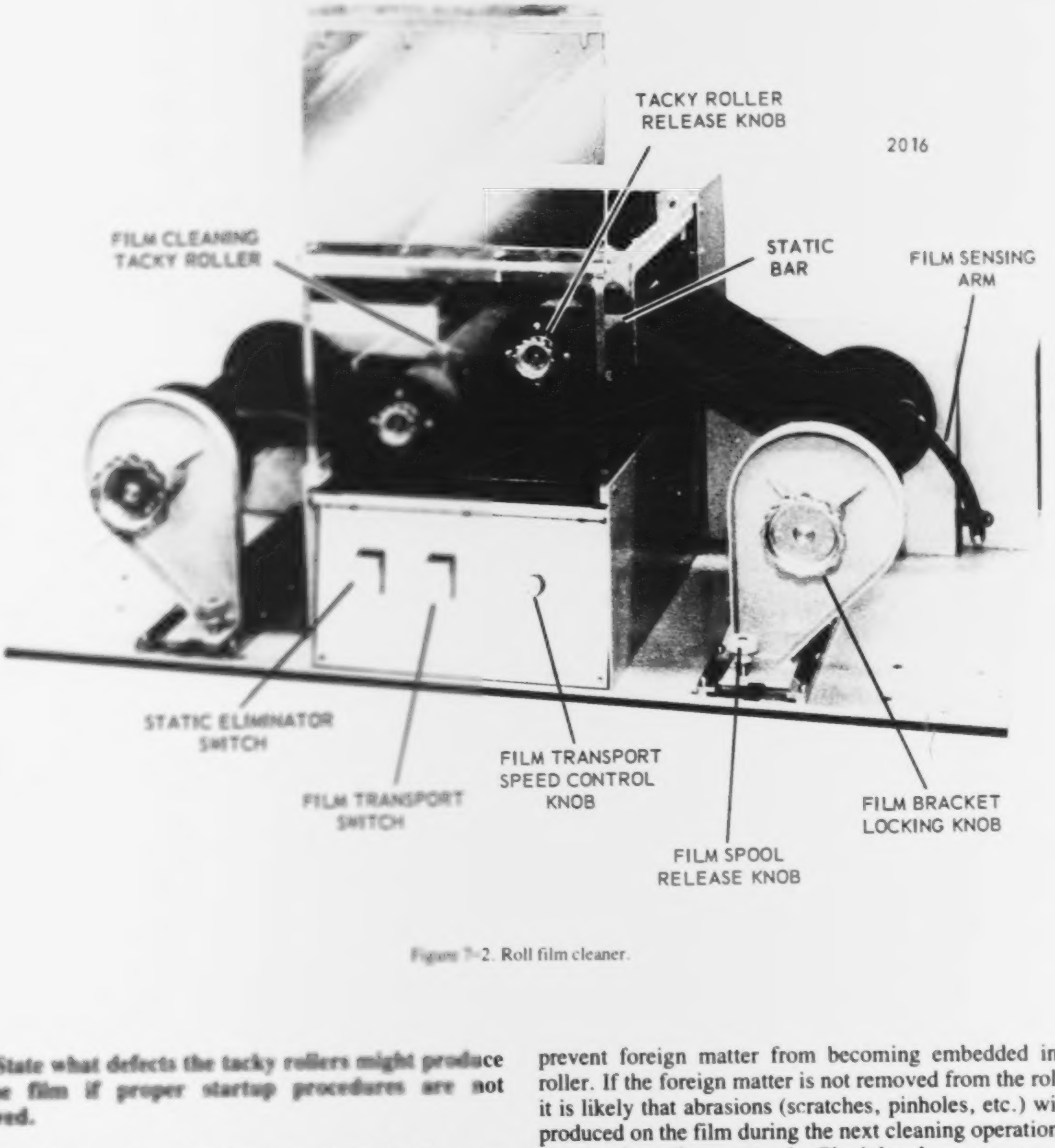
TACKY ROLLER
RELEASE KNOB
2016
FILM CLEANING
TACKY ROLLER
STATIC
BAR
FILM SENSING
ARM
STATIC ELIMINATOR
SWITCH
FILM TRANSPORT
SWITCH
FILM TRANSPORT
SPEED CONTROL
KNOB
FILM BRACKET
LOCKING KNOB
FILM SPOOL
RELEASE KNOB

Figure 7-2. Roll film cleaner.

488. State what defects the tacky rollers might produce in the film if proper startup procedures are not followed.

Tacky Rollers. Two tacky rollers clean the film; one contacts the base side and the other contacts the emulsion side. Both rollers are inclosed in a Plexiglas housing to keep dust from contaminating the roller surfaces. The rollers are accessible through a door located on the front of the compartment, and they may be removed for cleaning by depressing a spring-loaded mandrel which releases both ends of the rollers.

CAUTION: *When threading the cleaner, be sure that the film is correctly lined up form spool to spool. If not properly aligned, the stress placed on the material might result in the emulsion being stripped from the film base. The adhesive quality of the tacky rollers prevent normal correction shifting of the film during operation.*

The tacky rollers should be cleaned quite frequently to prevent foreign matter from becoming embedded in the roller. If the foreign matter is not removed from the rollers, it is likely that abrasions (scratches, pinholes, etc.) will be produced on the film during the next cleaning operation. To remove the rollers, open the Plexiglas door, grasp a roller firmly by the end, pull roller retaining knob, and lift out the roller. Clean the rollers by washing them in lukewarm water. If available, use distilled water. Do not use a soap-base cleaner. Dry the rollers with a stream of compressed air. NEVER use cloth or similar material for drying rollers since lint from the cloth will adhere to the rollers.

CAUTION: *Use extreme care when handling the tacky rollers. The material is extremely soft and can be easily damaged. Handle the rollers only by the outer edges to avoid damage by finger imprints. Store the rollers in a vertical position. Under no condition should the rollers ever be stored horizontally, or in contact with any surface. The soft material of the rollers will become deformed if they are stored under such conditions.*

Exercises (488):

1. What defect might be produced in the film for the following situations?

   a. The film is not lined up properly between spools.

   b. Foreign matter becomes imbedded in the tacky roller.

   c. The rollers are wiped with a cotton cloth after cleaning.

   d. The rollers are placed on a table top for several hours after cleaning.

489. Sequence the procedure for adjusting film cleaners for various film widths.

Tacky Roller Film Spool Adjustment. After the rollers have been cleaned and reinstalled into the cleaner, the cleaner is ready for operation. The next step is to thread the machine with the material to be cleaned. Because the unit can clean different sizes of film, the film spool brackets may have to be adjusted.

Threading the cleaner. To thread the cleaner, loosen the knobs holding the film spool brackets. Slide the brackets in or out as required to accept spools of the film size being cleaned. Tighten the knob firmly when the correct spacing has been obtained.

Place the roll of film to be cleaned on the left loading bracket by pulling the knob of the movable bracket and inserting the spools onto the pins. Then open the Plexiglas door on the front of the machine located on the control panel, and using your left hand, pull the film from the supply spool, pass it under the first tacky roller in the Plexiglas cabinet, over the second tacky roller, and on to the takeup spool.

Place the sensing arm roller against the film. This roller is located at the rear of the machine on th[illegible]keup side. The sensing arm controls the motor speed to insure a constant driving speed.

Exercises (489):

1. The following procedures are used for adjusting the film cleaner for certain width film and for machine threading. Arrange these procedures in their proper order.

   a. Place the roll of film on the left loading bracket.

   b. Place the sensing arm roller against the film.

   c. Open the Plexiglas door.

   d. Loosen the knobs holding the film spool brackets.

   e. Pass the film under the first tacky roller.

   f. Slide the brackets in and out as required to accept the film spools.

   g. Pass the film over the second tacky roller.

   h. Tighten the knobs firmly.

490. Explain the cause of improper cleaner operation as related to film spool adjustments.

Effects of Improper Film Spool Bracket Adjustment. Adjusting the film spool brackets and threading the cleaner are simple tasks. For this reason, even the most unskilled operators make very few mistakes. One only has to move both the supply and takeup Brackets forward to hold the film spools, to tighten the knobs that hold the brackets in place, and to position the sensing arm roller against the material takeup spool. If these are not done correctly, probably no damage will be done to the materials being cleaned. However, since the entire roll of film might have to be recleaned, negligence in performing these tasks could waste manhours. Even as simple as these tasks are, it should be emphasized that failure to accomplish them correctly will result in improper machine operation. That is, if the bracket on the takeup end of the unit is not properly positioned, the motor drive cannot turn the takeup reel which pulls the film through the cleaner. Failure to correctly position the supply bracket will result in drag tension not being applied during operation. Furthermore, the supply and takeup reels might fall off, or be pulled off the brackets. Also, the sensing arm must be properly positioned if constant transport speed and drag tension is to be maintained.

Exercises (490):

1. What would cause the following situations?

   a. The film cleaner operates, but the film does not transport.

   b. The supply spool falls off during operation.

   c. During operation, the material transport speeds up as the supply roll becomes smaller.

491. Cite the best solution for each problem given that might occur as a result of improper transport speed.

Tacky Roller Transport Speed. The final step in cleaner setup is to establish the optimum film transport speed. It should be remembered at this point that the cleaner must be threaded with the material to be cleaned. For this reason this task could also be considered as part of the actual operation.

Within its operating speed range, the film transport speed is variable to allow optimum setting for particular conditions. A sensing arm rides on the takeup spool to maintain speed with ± 15 percent of set speed. To prevent static buildup on the takeup spool, a static eliminator is mounted at the film exit of the roller enclosure. This high-voltage static eliminator is capacitance coupled to the voltage source to prevent a shock hazard to operating personnel.

The actual transport speed needed for any film depends upon the physical state of that film. The more dust, lint, etc., that is on the film, usually the slower the cleaner must be run. Always start a cleaning operation at a relatively low speed. The speed may then be increased to maximum if the cleaner is removing all of the foreign matter. A close visual inspection of the material must be maintained so that the transport speed can be adjusted to facilitate cleaning.

Exercises (491):

1. What should be done if the film cleaner is not removing all the dust from the film?

2. A new operator threads the film cleaner with a 1,000-foot roll of film. He or she begins the cleaning operation at an extremely low speed which thoroughly cleans the film. However, at the operating speed, it will require approximately 1 hour to clean the film. As a supervisor, what should you do?

492. State the result of malpractices that might occur during Tacky Roller Film Cleaner operations.

Operation of the Tacky Roller Film Cleaner. Now that the cleaner has been prepared for operation, let's look at the actual operating steps. Once you have threaded the cleaner, actual operation is a simple matter. The following steps should be followed: (Refer to fig. 7-2 while reading these steps.)

(1) Turn the transport speed knob counterclockwise to zero and engage the transport switch. Otherwise, the transport motor could burn out if the transport mechanism had been set at a high speed.

(2) Turn the static eliminator switch to the ON position by pressing the upper portion of the switch is. This switch operating when the transport system is energized. The cleaning unit can be operated without the static eliminator, but this is not recommended because the intense static charge generated by the two tacky rollers would attract more dust and dirt to the film.

(3) Energize the transport system by pressing the upper portion of the film transport switch.

(4) Turn the transport speed control knob clockwise to obtain the desired operating speed. The transport system is designed to operate up to 135 feet-per-minute ±15 percent. Maximum cleaning is obtained with the slower operating speeds.

(5) As a safety precaution, it is desirable to turn the transport speed control knob to zero before deenergizing the transport drive.

(6) To reduce outside contamination, the cleaning unit should be covered when not in use. Also, unless it is covered, dust and dirt might become embedded in the tacky rollers and damage film that is being cleaned.

Exercises (492):

1. What could happen if the transport speed is not set on zero when the cleaner is turned on?

2. If the static eliminator unit is not activated during cleaning operations, what will result?

3. If the cleaner is not covered when not in use, what is likely to happen?

493. Explain the operation of the Ultrasonic Film Cleaner.

Ultrasonic Film Cleaner. One of the newest tools used in film cleaning is sonic energy. Sound is vibrational energy. This energy is harnessed for use in a cleaning method. The method requires that the film to be cleaned is passed through a liquid. Normally, this would only float off

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some of the dirt particles. If the film or solution were to be agitated, additional particles of dirt would be removed.

The application of ultrasonic (above an audible range) energy provides a high degree of solution agitation by means of the cavitation principles. Cavitation is the formation of airspaces or cavities in a solution. The airspaces, or bubbles, are very small. Actually, they are submicroscopic and appear throughout the liquid at the surface of film when the film is immersed in the liquid. A sound wave sent through the liquid will compress and collapse the submicroscopic airspaces and leave a void. The rushing liquid is driven by hydrostatic pressure, atmospheric pressure, and surface tension. The rushing in of liquid and the reformation of airspaces are in resonance with the frequency of the sound; and as a result, a type of scrubbing action occurs. The cleaning action is quite effective because it reaches the entire surface of the film in contact with the cleaning solution. Care must be exercised in selecting a cleaning solution which will not decompose under ultrasonic energy pressure.

Ultrasonic film cleaning is an actual proven practice and not merely theoretical. A cleaner will clean rollfilm up to 9.5 inches in width, in lengths of up to 500 feet. This is a motor driven machine. Film is passed through a cleaning fluid, and ultrasonic vibration is applied at the same time. In general, the machine is used to clean very dirty film to make it suitable for reproduction.

Exercises (493):

1. Describe cavitation.

2. What is the method of cleaning used in the ultrasonic?

7-4. Titler Shutdown Procedures

After all film has been titled, shutdown of the dual-head titler must be performed.

494. Specify the effects of improperly performed shutdown procedures on the dual-head titler.

Shutdown Procedures. Operation of the dual-head titler is not complicated; the same is also true of its shutdown procedures. Properly performed shutdown procedures prolong the life of the equipment, and this should be remembered whenever any piece of equipment is shutdown.

Once the film titling operation has been completed, the titler is ready for shutdown. The procedures for shutdown are as follows:

- Move the titler heads to the raised position to keep from forming a flat spot in the rubber-covered tape drive roller.
- Turn off the air supply.
- Set the main power switch to the OFF position.
- Set the timer switch to the OFF position.

What do you think would happen if these shutdown procedures are not performed properly? Let's take a moment to list some of the effects of improperly performed shutdown procedures:

(1) A flat spot on the rubber-covered tape drive roller will cause the titling tape not to advance properly. The titling tape must advance enough to prevent superimposition of characters on the tape.

(2) Leaving the titling heads down on the titler after performing shutdown procedures can cause the pigment in the titling tape to stick to the heated type. It also can cause the flat spot (mentioned in the above paragraph) to develop on the rubber covered tape drive roller.

There are others that you could name, but if you are the operator, perform the shutdown procedures properly, and there won't be any effects to worry about.

Exercises (494):

1. What effect will a flat spot on the rubber-covered tape drive roller have on titling film?

2. What two effects could result from leaving the titling heads down after performing shutdown procedures?

7-5. Troubleshooting Film Cleaners

As with any piece of photographic equipment, the film cleaner will not run indefinitely without malfunctions. For this reason, troubleshooting tables for most cleaners are published in the applicable technical order (TO).

495. Use table 7-1 to determine the probable cause(s) and indicate corrective measures for listed Tacky Roller Film Cleaner trouble symptoms.

Trouble Symptoms. Table 7-1 is the troubleshooting data for the Tacky Roller Film Cleaner as given in TO 10C2-1-41. Such troubleshooting tables should be available in each imagery production facility that uses the Tacky Roller Film Cleaner. It should be emphasized here that the Corrective Measure column of this troubleshooting table is not for operator use. References to specific capacitors, resistors, diodes, etc., in this column are as they appear in the applicable TO and are for maintenance personnel use only.

Exercises (495):

1. Use table 7-1 to determine the cause(s) and corrective measures for the following Tacky Roller Film Cleaner trouble symptoms:

   a. The cleaner motor runs but the film does not transport.

TABLE 7-1

TROUBLESHOOTING DATA

(Tacky Roller Film Cleaner)

TROUBLE SYMPTOM	PROBABLE CAUSE	CORRECTIVE MEASURE
Motor circuits not energized when FILM TRANSPORT switch is on.	Power not available at electrical cord.	See that electrical cord is plugged into "live" 115-vac receptacle.
	Blown or missing fuse	Insert good fuse in MOTOR 4 AMP fuseholder.
	FILM TRANSPORT switch or wiring defective.	Check for circuit continuity, and replace switch or repair wiring.
Fuse blows when FILM TRANSPORT switch is on and TRANSPORT SPEED control is at zero.	Field rectifier in motor controller shorted.	Disconnect motor field, check for shorted rectifier elements (CR1 through CR6), and remove short or replace defective part.
	Silicon control rectifier in motor controller shorted or grounded.	Check for shorts between rectifier (SCR) terminals and to chassis ground, and remove short or replace rectifier.
	Motor field shorted or grounded.	Disconnect motor leads, measure field resistance (800 to 900 ohms), check for short to frame, and remove short or replace motor.
	Interconnecting wiring shorted or grounded.	Inspect wiring from fuseholder to motor controller and to motor field, and remove any short.
	Printed circuit board in motor controller shorted or grounded.	Check circuit continuity and isolation, and see that board is insulated from chassis.
Fuse blows when TRANSPORT SPEED control is turned clockwise.	Motor overloaded.	Remove film transport drive belt to isolate trouble, and correct overload condition.
	Motor armature shorted or grounded.	Disconnect motor leads, measure armature resistance (5 to 9 ohms), check for short to shaft, and remove short or replace motor.
	Silicon control rectifier in motor controller shorted or grounded.	Check for shorts between rectifier (SCR) terminals and to chassis ground, and remove short or replace rectifier.
	Filter in motor controller shorted or grounded	Disconnect motor armature leads, check for shorted capacitors (C3, C4) and resistors (R5, R6), check for low coil resistance or short to frame of choke (L), and remove short or replace defective part.
	Bias network in motor controller shorted or grounded.	Check for shorted capacitors (C1, C2, C3), resistors (R5, R6), and diodes (CR7, CR8) check for shorts to chassis ground, and remove short or replace defective part.
	Printed circuit board in motor controller shorted or grounded.	Check circuit continuity and isolation, and see that board is insulated from chassis.
Fuse does not blow and motor will not run when power is applied by FILM TRANSPORT switch.	Silicon control rectifier in motor controller defective.	Replace silicon control rectifier (SCR).
	Filter choke in motor controller open.	Check coil continuity, and replace defective choke.
	TRANSPORT SPEED control or sensing arm potentiometer open.	Check circuit continuity, and replace defective potentiometer.
	Diode in motor controller open.	Replace defective diode (CR7 or CR8)
Motor runs when TRANSPORT SPEED control is at zero, and speed can be varied.	Trimmer potentiometer in motor controller set incorrectly.	Adjust trimmer potentiometer (R4) for 10 volts DC across motor armature when TRANSPORT SPEED control (R1) is at 90 percent of clockwise rotation and sensing arm potentiometer (R2) is at counterclockwise limit.
	Printed circuit board in motor controller defective.	Repair or replace printed circuit board.

TABLE 7-1 (Cont'd)

TROUBLE SYMPTOM	PROBABLE CAUSE	CORRECTIVE MEASURE
Motor runs at essentially same speed regardless of setting of TRANSPORT SPEED control.	Silicon control rectifier in motor controller defective.	Replace silicon control rectifier (SCR).
	Bias diodes in motor controller defective.	Replace diodes (CR7 and CR8).
	TRANSPORT SPEED control or wiring defective.	Replace potentiometer (R1), or repair wiring.
	Motor brushes defective.	Replace brushes.
	Motor defective.	Replace motor.
Motor runs but film is not transported.	Drive belt defective or missing.	Install good drive belt.
Speed of film travel not essentially constant throughout length of film roll for given setting of TRANSPORT SPEED control.	Sensing arm not in indicating position.	Position sensing arm so that roller rides on edge of film.
	Sensing arm potentiometer not adjusted correctly.	Adjust potentiometer.
	Sensing arm loose on shaft or aligned improperly.	Align arm.
	Sensing arm potentiometer or wiring defective.	Replace potentiometer (R2), or repair wiring.
Slack occurs in film at supply mandrel for selected operating speed.	Friction brake adjusted improperly.	Adjust brake.
	Friction brake defective.	Replace defective part of brake assembly.
Static bar not energized when both STATIC ELIMINATOR and FILM TRANSPORT switches are on.	Toggle switch of static eliminator power supply not on.	Remove compartment access cover and set switch to ON position.
	Blown or missing fuse	Insert good fuse in STATIC ELIM 1/2 AMP fuseholder.
	Electrical cable not connected to static bar.	Make certain that cable connector is properly tightened.
	STATIC ELIMINATOR switch or wiring defective.	Replace switch (S2), or repair wiring.
	FILM TRANSPORT switch or wiring defective.	Replace switch (S1), or repair wiring.
	Static bar, power supply, or interconnecting cable shorted or otherwise defective.	If shorted or defective condition is not readily apparent or cannot be corrected easily, replace entire unit.

b. Slack occurs in the film at the supply end.

c. Film transport speed not constant.

7-6. Preventive Maintenance of Titlers and Cleaners

As previously discussed in this CDC, properly accomplished preventive maintenance tasks insure longer life for equipment, and in many cases, insure higher quality photographic products. In this section, we briefly discuss the preventive maintenance tasks associated with film titlers and cleaners.

496. Explain why listed preventive maintenance functions are necessary.

Common Preventive Maintenance Tasks. Preventive maintenance begins with good housekeeping. This simply means that the equipment and surrounding area must be kept immaculately clean. Otherwise, accumulations of dust, lint, dirt, etc., on the equipment can easily be transferred to the film and retained there by static electricity. Furthermore, some foreign matter is extremely hard and can produce abrasions when subjected to friction.

Another important preventive maintenance task is lubrication. The correct type and amount of lubrication at the recommended time intervals prevents wear and ambient heat buildup and results in smoother equipment operation because of decreased friction. Excessive lubrication is as bad as, if not worse than, no lubrication at all. The equipment manufacturer itemizes lubrication contact points and recommends a schedule for lubrication. This information can usually be found in the applicable TO or in the operating instructions that come with the equipment.

Other tasks are required. The previous two are common to all equipment. In the following paragraphs we investigate other preventive maintenance tasks for the three pieces of equipment discussed throughout this chapter.

Exercises (496):

1. Why is cleanliness of equipment necessary?

2. Why is proper lubrication of equipment necessary?

497. Determine and explain the probable results if listed preventive maintenance functions are not accomplished.

Specific Preventive Maintenance Functions. As previously stated, each different piece of equipment requires different preventive maintenance functions. Let's now categorize them according to equipment.

Dual-head titler. All good housekeeping procedures that are normal for photographic equipment apply to the dual-head titler. In addition, you should brush all flakings from the tape off the printing table, the counters, and the lead type daily. Vacuum all surfaces around the printing areas to remove flakings. Exercise extreme care to be sure that the flakings do not become wedged in the roller bearings. To prevent a buildup of the flakings on the rollers, wipe off all rollers on the printing heads. The rollers should be cleaned with solvent periodically.

Tacky Roller Film Cleaner. Your maintenance procedures for this machine are largely a matter of keeping it clean. Since the purpose of the machine is to keep the film clean, it follows that a dirty cleaner cannot be very effective.

The Plexiglas housing should be cleaned with nonstatic Plexiglas cleaner as required. At this time, refer back to the text segment for Objective 488 for other comments concerning the Tacky Roller Film Cleaner.

Exercises (497):

1. What might result if the titling tape flakings are not removed from the dual-head titler?

2. Why is it important that the rollers on the dual-head titler be clean?

3. Why is it necessary to dry the tacky rollers with compressed air instead of a cloth?

Printing

PREVIOUSLY, we discussed film processing. You recall that the accent was on processing the original negative. You now have on hand an original one-of-a-kind film. In the field of high altitude reconnaissance photography, the original negative is a priceless item. The negative has given us a permanent record of a vast amount of detail within the view of the camera lens. The detail was acquired only through careful planning and great expense. Furthermore, information the negative contains may be of such a nature that it can never again be obtained.

Our roll of negatives can be studied and restudied for various reasons, but in order to study it, you must view it. However, viewing requires a certain amount of handling and an attendant risk of potential damage. Additionally, it is usually desirable to disseminate information, obtained from the negatives, among various Air Force organizations. With only one roll of negatives, this is impossible. Therefore, the negative roll must be reproduced.

In this chapter, we cover the subject of reproducing the dupe pos and dupe neg. These in turn can be used to reproduce any number of subsequent generations later on in the reproduction cycle.

You will find that printing is one of the primary tasks of the imagery production lab. Whether you are making a positive transparency or a duplicate negative from the original, it is imperative that any loss of information be held to an absolute minimum. The image must not be degraded. Printing is an exact science. Thus, utmost control must be maintained so that little or no loss of image occurs.

8-1. Printer Mechanical Certification Functions

The purpose of any printer is to transfer, with a minimum amount of distortion, degradation, and other losses, the information content of processed photographic materials to duplicating materials. The ability to accomplish this task is quantitatively and qualitatively evaluated by the printer certification test. The recommended procedure consists of several tests which should be used periodically to evaluate the three general categories of printer performance: illumination and exposure, image quality, and the physical quality of the materials.

498. State why given tests are required during mechanical certification of printers.

Purpose of Certification Tests. The primary function of a printer is to produce, at the printing aperture, a selected level of exposure in an accurate and uniform manner. The desired exposure level is implicity stated in the printing instructions that stipulate the printer control settings that are to be used for printing. Since the absolute quantity of the exposure in meter-candle-seconds is generally unknown, the exposure requirement is actually expressed as a relative value.

The exposure at the printing aperture, or that incident upon the negative, is referred to as the printing exposure. It is not numerically equal to, and should not be confused with, the exposure incident upon the duplicating material. The latter can be computed by subtracting the density of the negative from the printing log exposure. When a roll of processed film is printed, the exposure is constant throughout the operation since it can be changed only by manipulating the controls. The duplicating material, however, receives a multitude of exposures due to the various densities of the negative. The importance of the printer's ability to produce the selected exposure level is reflected in the role that the printer plays in the tone reproduction process.

An evaluation of the illuminance uniformity across the printing aperture is made to detect conditions that cause streaks in the imagery, thus degrading the production quality. This test is based upon an evaluation of flashed imagery (made by a controlled exposure that produced a midtone density). Flashed imagery is also used to locate conditions that cause physical degradations to be imparted to either the original negative or the duplicating material.

An evaluation of the image quality is made to insure that the printer is not distorting or degrading the information contained on the original negative in the process of transferring it to the duplicating material. The printing of the image evaluation targets is frequently combined into one operation with the aid of a printer certification frisket. The certification frisket may contain targets for the evaluation of the following parameters of printer performance: resolution, linear distortion, slippage, and adequacy of the contact between the negative and the raw stock.

Exercises (498):

1. Explain why the following tests are required during mechanical certification of continuous printers:

   a. Illuminance uniformity.

b. Flashed imagery.

c. Image quality.

499. Given hypothetical results of mechanical certification tests, determine the cause of each unacceptable condition.

Certification Tests. In the following paragraphs, we discuss minimum tests that should be conducted during printer certification. The first of these is to certify the film transport rate.

Film transport rate. The variability of the film transport rate of continuous printers is of primary importance because it is inversely proportional to the exposure time. If the printer transport rate is incorrect or if it exhibits a high degree of variability, substandard exposures will be produced. A measurement of the film transport rate can be used as a measurement of the relative exposure time for continuous printers.

The recommended method for determining the film transport speed of a continuous printer is to use a tachometer to measure the surface speed of either a drive roller or pressure roller. The surface speed of the roller is equal to the transport speed of the film unless slippage occurs. This test method is applicable to all photographic facilities. The control limits of the test, however, may vary, depending upon the level of photographic quality the facility is striving to obtain, as well as the capabilities of the printers which are being evaluated. The printer must be threaded with raw stock and a simulated negative material when this test is performed. Because accuracy of the drive system is essential to proper printer performance, the film transport rate test should be the first test in the printer certification procedure.

Printing aperture illuminance uniformity. The purpose of this test is to detect variations in the light intensity across the printing slit. If the variations are not detected and corrected, the imagery will be streaked. Variations in the printing aperture illuminance can be due to a poorly aligned light source, dirty optics, a printer lamp being used beyond its useful life, and/or variations in the density of the printer's neutral density filter.

It is desirable to expose the test sample using 0.00 neutral density so that the test evaluates only the variation in illuminance due to the printer lamp and the optical system. If the printing instructions call for some value of neutral density to be used, then the test will measure the combined variation of the illuminance variation as well as the variations in density of the exposure modulator. If the 0.00 neutral density filter setting produces a developed density that falls on the shoulder of the response curve, the test has a low degree of reliability since minor differences in illumination would produce little or no detectable density difference. In order to circumvent the problem, a slow-speed material which would produce a midtone density at the maximum exposure value, could be used.

The raw stock is loaded as it would be for a normal printing operation. Since the exposures are made without using a processed negative which would modulate the exposure, the density of the processed imagery should be uniform. This type of imagery is usually termed "flashed material." Since the physical abrasion tests are usually combined with the illuminance uniformity tests, 50 feet of raw stock are exposed with each printer. After all the material has been exposed, a 90 precent turn-around splice must be made in the middle of each 50-foot section. Since the material selected for this test is usually blue-sensitive duplicating film, this can be done under safelight conditions.

The 90 percent turn-around splice insures that the test is not significantly influenced by any minor development uniformity problems that may exist. Since the evaluated portion of the turn-around splice is parallel to the direction of travel, all of the data points should receive the same degree of development. After processing, a segment of the turn-around splice is densitometrically evaluated. The remaining footage, including the rest of the turn-around splice, is used for the physical abrasion test. The turn-around strip may be evaluated either by using a recording densitometer or by reading a series of points across the width of the film and then plotting them with respect to distance. Both of these methods yield a plot of density versus distance across the film width.

Physical abrasion test. The purpose of the physical abrasion test is to certify that the printer is free from conditions which degrade the quality of the original negatives, or master duplicate negatives and positives.

The physical abrasion test is usually combined with the printing aperture illuminance uniformity test, since the test imagery required for both of these tests is the same. The location and identification of surface defects is considerably easier on flashed film than it is on film containing pictorial images. The flashed film is exposed, processed, and evaluated for scratches, abrasions, cinch marks, dimples, deckled edges, static marks, imbedded dirt particles, and other related problems. Since many of these conditions can be detected only on the side of the film that is viewed, both the base side and the emulsion side must be evaluated. Fine scratches that are located on the opposite side of the film from that which is being viewed are very difficult to detect. By comparing their orientation in the major portion of the sample to their orientation in the turn-around splice, continuous or intermittent physical defects caused by the printer are differentiated from those which are attributed to processing.

In addition to the physical quality of the film, the flashed image is scanned for illumination and processing problems. Some illumination uniformity problems are not easily detected from the recording densitometer trace of the printing aperture illuminance uniformity test. Fine streaks, such as those caused by scratches or nicks in the printer neutral density filter, are detected more easily during the physical inspection of the material. Since the physical abrasion test must be processed with a certified processor, few processing defects should be encountered.

Exercises (499):

1. Determine the cause of each of the following unacceptable certification test results:

   a. Visual streaks of density change across the width of duplicate.

   b. Varying duplicate densities for areas of identical original negative densities.

8-2. Printer Standardization Tests

When the previous tests have been completed and the evaluation of the tests indicates satisfactory printer conditions, acceptable duplicate products can be produced. However, one additional test should be conducted. This is the printer standardization test.

500. Cite the purpose for the several parts of a certification frisket.

Printer Certification Frisket. The printer certification frisket is generally designed to meet the specific facility requirements as opposed to being purchased as an off-the-shelf item. The tests that are employed depend upon the capabilities of the printers, the evaluation and measuring devices available, the desired thoroughness of the evaluation, and the image quality standards that are to be maintained. Recommendations on the design of a suitable frisket are usually provided by frisket and printer manufacturers.

Because the content of printing friskets varies significantly, it is impossible to present a test procedure that is typical of all, or even most, certification procedures. Therefore, this section is limited to a discussion of the problem areas associated with the tests included in the certification frisket, as shown in figure 8-1.

The frisket frequently is not one continuous piece. Generally, it consists of several materials spliced together. A typical frisket may include the following tests: resolution targets, reseau marks to evaluate the dimensional accuracy of the reproduction, a graphic arts tint screen to provide subjective evaluation of slippage (crab and crawl), and a step tablet or continuous wedge to determine if the frisket has been properly exposed and processed.

Exercises (500):

1. Cite the purpose for the parts of a certification frisket which follow:

   a. Reseau marks.

   b. Graphic arts screen.

   c. Step tablet or continuous wedge.

501. Given a list of unacceptable conditions as indicated by the standardization tests, explain how these conditions would affect the duplicated product.

Evaluation of Standardization Tests. The primary purpose of the printer standardization test is to evaluate the quality of the printer's imaging ability. The most commonly used method is to position several rows of resolution targets across the width of the frisket. Special skills, equipment, and materials are required to produce resolution targets that are suitable. Since few facilities have these capabilities, printing friskets are generally purchased from outside sources. To enable all image areas to be evaluated, the width of the frisket should be equal to the maximum width that the printer is capable of handling. Even though the mission may involve only narrow width materials, the full width (usually 9½ inches) of the printing aperture is evaluated.

The resolution targets are usually white lines on an opaque background with a contrast range in excess of 1000 to 1. The maximum resolution value of the targets are usually 50 percent greater than that of the printer-film combination. If, for example, a printer is expected to yield a resolution capability of 300 lines per millimeter, the maximum resolution value of the resolution targets will normally be in excess of 450 lines per millimeter.

The ability of the printer to maintain dimensional accuracy is evaluated by sets of reseau marks. The placement of reseau marks requires a higher degree of precision than that associated with the drawing of fiducial marks. Reseau marks can be in the form of either crosshairs or dots. The frisket generally contains at least two sets, one to represent the frame length and one to represent the frame width. The comparison of the distances between the reseau marks on the frisket to those on the duplicate image are made by using an optical comparator or a microdensitometer.

A graphic arts screen tint is often included in the printing frisket to permit a subjective evaluation of the contact between the negative and raw stock. When the contact between these two items is insufficient, the periphery of the dot image is degraded to a soft edge. If slippage occurs in the direction of the film travel, the leading and trailing edges of the dots are soft while the side edges are relatively sharp. This condition, which is caused by one of the materials being transported at a faster rate than the other, is referred to as *crawl*. If the leading and trailing edges are sharp and the side edges are blurred, the printer is exhibiting *crab*, caused by one of the two materials slipping in the direction perpendicular to that of the film transport. A screen tint is used for this test rather than a regular graphic arts contact halftone screen since the latter item produces dots which have relatively soft edges.

Because the exposure level used to expose the frisket is critical, the printer certification frisket test is generally the last test to be performed in the printer certification

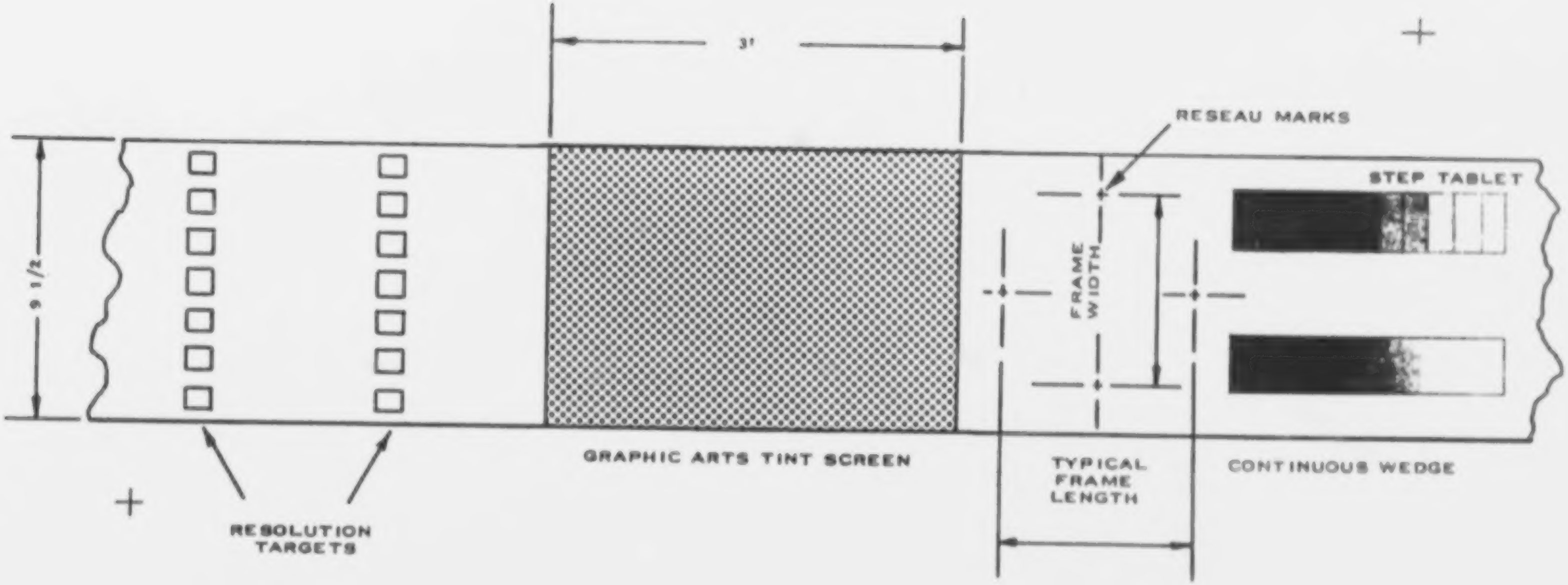

3"
RESEAU MARKS
STEP TABLET
FRAME WIDTH
9 1/2
GRAPHIC ARTS TINT SCREEN
TYPICAL FRAME LENGTH
CONTINUOUS WEDGE
RESOLUTION TARGETS

Figure 8-1. Sketch of printer certification frisket.

procedure. To optimize the resolution values, the exposure must be uniform and accurate. Since the exposure of the resolution targets is critical, the printing instructions vary, depending on the degree of development (gamma) to which the material will be processed. If the material is to be processed to a high contrast, the printing instructions will call for more neutral density (less exposure) than that required for material processed to a medium or low contrast. The resolution produced by the printer will also vary to some extent based upon the degree of processing used. Therefore, separate control limits for the resolution test must be determined if more than one level of development or film type is used.

To provide an exposure and processing check in the event of a certification failure, a continuous neutral density wedge or step tablet is often included as part of the frisket.

Exercises (501):

1. Explain what effects the following unacceptable standardization test results would have on the duplicated product:

   a. Decreased distance between reseau marks in the duplicate in the direction of the film travel.

   b. Increased distance between reseau marks on the duplicate perpendicular to the direction of film travel.

   c. Soft leading and trailing edges of the graphic arts screen tint.

8-3. Optical Certification

Some printers used in the Air Force are classified as optical printers. These are printers which use a lens system to project the image being printed across an air gap. When these types of printers are used, an additional certification must be performed. This is the optical certification.

502. List the tasks to be performed during preparation for operation and certification of an optical printer.

Optical Certification Tasks. Optical printers are unique in that both a camera and a projector are used. The camera, similar in many ways to a typical motion picture camera, records the image produced by the projector.

A typical optical printer is the "Acme 104." With this system, an original can be enlarged, reduced, or copied 1:1.

A 103-mm, f/2.8 lens is used for 1:1 copy and affects work in either black-and-white or color. The 90-mm lens is used for enlargement or reduction of black-and-white or color.

As with all lenses, these lenses must be checked for separation of elements, chips, and scratches before they are used. Also, they must be cleaned of fingerprints, dust, and lint.

After the correct lens is installed, the camera must be aligned. This is done by placing a strip of standard-format film in the gate of the projector and turning the lamp on at a low voltage. The viewer (reflex mirror) is opened on the camera by pulling the small lever located behind the aperture opening adjustment. The lens is adjusted horizontally and vertically, to center the image, with two knobs on the lens mounting. Image size is adjusted by turning the smaller knob directly under the lens. A crank handle, located at the far right side of the machine, allows positioning of the camera for proper focus.

The condenser system is placed in proper relationship with the lamp by moving a knob on the top of the lamp housing. This knob allows positioning for 35–16, 1:1, and 16–35 operation and is marked accordingly.

Exercises (502):

1. What are the tasks that must be performed during preparation for operation and certification of the "ACME 104" printer?

8-4. Printer Correlation

If the tone reproduction system is to meet the stringent quality standards of an imagery production laboratory, it is essential that all of the production printers are able to produce, at specific control settings, known exposure levels. The capability of the production printers to meet this requirement is evaluated through the use of the printer correlation test.

503. Given correlation tasks, explain why the tasks are done accomplished in a specific manner.

Printer Correlation Test. The printer correlation test is used to compare the printing exposures of all printers to the exposure of the standard printer. If it is found that some of the printing exposures are significantly different from that of the standard printer, the test data is used as a basis for estimating a new lamp control setting that will result in an "in-standard" printing exposure.

To minimize the variability of the test procedure introduced by the photographic materials, all exposures of the printer correlation test are made on one roll of raw stock. The roll of raw stock selected for this test need not be control stock, nor does it require special storage. The only restrictions in the selection of the raw stock are that the inherent sensitometric properties of all the test samples be the same, and that they be similar to those of the mission materials. The first requirement is met by making all of the test exposures on the same roll of film or on samples taken from the same roll of film. The second requirement can be met by selecting the raw stock from the rolls of film that have been certified for mission use. This insures that a sample of that particular emulsion has been tested to verify that the sensitometric characteristics are suitable for use. If several different films are to be used, one test is sufficient as long as the sensitometric characteristics of the various mission materials are similar; e.g., blue-sensitive duplicating films. If the films are significantly different, as in the case of a blue-sensitive duplicating film and a panchromatic material, it may be desirable to perform a test with each type. If the correlated printer has a spectral energy distribution that is slightly different from that of the standard printer, it is possible that a correlation test performed with a blue-sensitive material would show that the printer is in standard. When these printers are evaluated with the use of panchromatic emulsion, however, the test results may indicate that they are significantly different.

The step tablet exposure of the test strips is accomplished with the sandwich technique. Since the exposed area surrounding the step tablet image will have maximum density, the amount of footage exposed per test should be kept to a minimum. This will minimize the bromide buildup in the developer when the test material is processed. For this reason, 70-mm raw stock is often preferred over the wider films.

If the printer's transport path is such that 10 to 15 feet of film pass under the printing aperture for each step tablet exposure, process only the 2- or 3-foot film sample containing the step tablet exposure and discard the remainder of the fogged test film. The method selected for exposing the step tablet will vary, depending on the design of the printers which are used. If the method adopted consists of making all of the exposures on one continuous piece of film, care must be taken to insure that this technique does not fog that portion of the raw stock that contains an exposure from another printer.

This method of exposing the test strips is applicable to printers such as the Niagara and Belair models. The first exposure is made on the standard printer using the sandwich method. As soon as the step tablet emerges at the idler roller, the transport mechanism is turned off. The location of the image is then marked and the sample is properly labeled. The raw stock, located partly on the supply spool and partly on the takeup spool, is then transferred from the standard printer to the first printer to be correlated. The carrier material is similarly transferred. The transport mechanism of the second printer is engaged and a second step tablet is made. This process is repeated until all of the printers have exposed samples for correlation certification. The first section of film contains the reference exposure from the standard printer, the second section contains the exposure of the first printer to be correlated, the next section from the second correlated printer exposure, etc. In addition to being relatively fast, the need to make splices or wind the film onto one spool after each exposure is eliminated.

After each exposure is made, the film sample must be labeled with the pertinent information. This includes: the name of the test, the date, the printer number, and an arrow to indicate the proper orientation of the film sample during processing. If only the 2- to 3-foot section containing the step tablet exposure is going to be processed, then that portion should be clearly marked so that the film can be cut at the proper locations.

Because of the time interval between the first and last exposure, one must age the test film for approximately 1 hour after the last exposure has been made. As you know, latent images deteriorate rapidly for approximately 1 hour after exposure. After this time period, there is very little or no additional deterioration. As a check against having the first exposure decaying significantly more than the last exposure, it is desirable to expose two standard printer reference exposures per roll. They should be the first exposure and the last exposure made on the roll. If, when the data is evaluated, these two curves are not appreciably the same, the test is invalid and should be repeated with either the aging period extended or the time between the first and last exposure decreased. The test samples must be processed to either a medium or high contrast on a processor that has been certified.

Printer Tone Control Tests. Correlation tests are being replaced by printer tone control tests. The tests are similar, but with tone control tests, each printer must compare favorably with the exposure used to produce one of the reference tone curves, instead of with the standard printer.

Exercises (503):

1. Explain why the following correlation tasks must be performed:

   a. Exposing all tests on one roll of raw stock.

   b. The use of only short lengths of film during testing.

   c. Making two tests from the standard printer.

   d. Aging all tests before processing.

504. Given hypothetical correlation problem situations, state the action that should be taken to correct each situation.

Analysis of Correlation Tests. The test strips are evaluated with a certified densitometer and the data are plotted on a single sheet of graph paper. Each response curve should be identified by the printer identification number. If more than one reference exposure has been made, the raw stock should be examined to verify that the two response curves are appreciably the same. If they are significantly different, the entire test procedure should be repeated, using a longer aging period. If the two sets of data from the standard printer are in agreement, the data should be averaged, and the average response curve should be used to represent the standard printer.

The log H displacements of the correlated printer response curves from the reference curve should be determined. The log H difference should be determined at a density of 0.60 (in the lower region of the straight line portion of the response curves). The exposure differences are then compared to the test control limits to determine which of the printers are certified under the printer correlation test. Printers which differ in printing exposure by an amount greater than the allowable tolerance must be adjusted. This printing exposure difference is indicated by high test densities for overexposure and low test densities for underexposure.

If the operator believes that the printer is out of control or if it has not been correlated for an appreciable period, the time required to certify all of the printers under the correlation test can be shortened considerably. This is done by making three exposures with each printer: one exposure at the normal lamp intensity control setting, one that would provide approximately 10 percent less exposure, and a third that would provide approximately a 10 percent greater exposure. If a printer is certified at the normal lamp intensity control setting, the two additional exposures (plus and minus 10 percent) would be discarded. If a printer failed to certify at the normal control settings, either the plus or the minus 10 percent response curve would be used to enable the operator to estimate a printer control setting that would result in the printer being certified under the correlation test.

The following example illustrates how the additional exposures are used to compute the trial lamp control setting for the printer correlation retest.

TEST DATA

Lamp Control Setting	*Difference in Log E from Standard*
	Printer
Normal	− 0.06
+ 10%	+ 0.03
− 10%	− 0.15 (not used in the computation)

Computation of Trial Exposure:

Log E difference produced by + 10% exposure versus normal exposure = + 0.03 −(− 0.06) = + 0.09

Amount of increase in the normal exposure required to equal the exposure of the standard printer = + 0.06

$$\frac{+0.06 \log E \times +10\% \text{ exposure}}{+0.09 \log E} = +6.6\%$$

Trial exposure lamp control setting for retest exposure = + 7%

Exercises (504):

1. Correlation tests exposed on the standard printer differ significantly. Additional tests are exposed, and the aging time increased, but the tests still differ. What could cause this?

2. One printer's curves reflect too much exposure. Is this indicated by the test strip containing low or high densities?

8-5. Printer Startup Procedures

After the printers have been mechanically certified, certain startup tasks must be performed prior to operation. Each type of printer has its own tasks that must be performed. As an example, we will use the tasks that are required for the Niagara printer for conventional printer startup procedures, and touch on the tasks of the Cayuga printer for computerized printer startup procedures.

505. List and explain tasks that must be performed during startup of the Niagara.

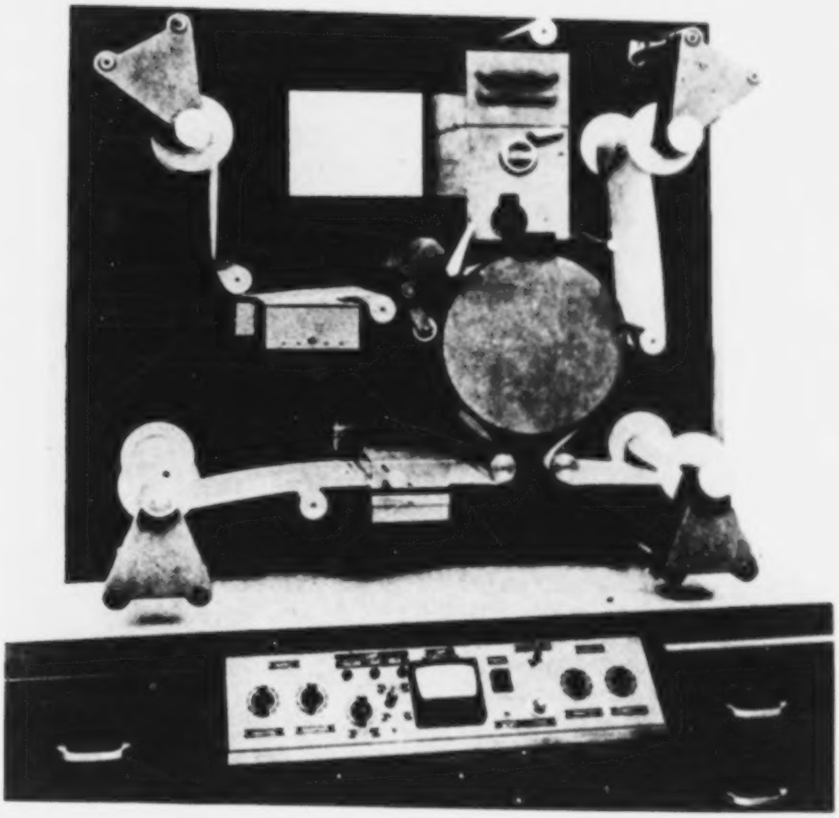
Preoperative Functions. The Niagara, illustrated in figure 8-2, is a high-resolution, low-distortion printer designed to produce duplicate films in continuous rolls at an operating speed of 100 feet-per-minute. The printer can accommodate lengths up to 1,000 feet of original negative. Used under darkroom conditions, the printer can expose any width of film from 70 mm to 9.5 inches, and is indexed from 70-mm, 5-inch, 6.6-inch, 8-inch, and 9.5-inch film wound on standard Air Force aerial roll film spools. The printer can also print up to three widths of 70-mm film on a single width of 9.5-inch raw stock. Original and raw stock are simultaneously moved in close registration past the constant light source.

To prepare the printer for operation, the main power switch is turned to the ON position (fig. 8-3). After this action, an 8-minute delay allows the printing lamp to stabilize. However, if it is necessary to test printer operation, you can run the printer without waiting for the lamp to stabilize.

By pressing the lamp interlock void button, the printer is made operable for test operation. When the lamp interlock void button is pressed, the lamp void light illuminates, indicating that the printer is still in the first 8 minutes of operation. After the test operation has been performed, the lamp void light can be cancelled by pressing the void cancel button. However, the lamp void light automatically goes out without pressing the void cancel button when the 8-minute timer runs out—warmup period completed.

Before an actual printing mission is performed, there are certain things that you must do. They are as follows:

- Adjust spindles and support brackets.
- Adjust torque controls.
- Thread negative and raw stock.
- Insert masks.
- Adjust variable neutral-density wedge.
- Position the ultraviolet transmitting filter.
- Adjust printing lamp intensity.



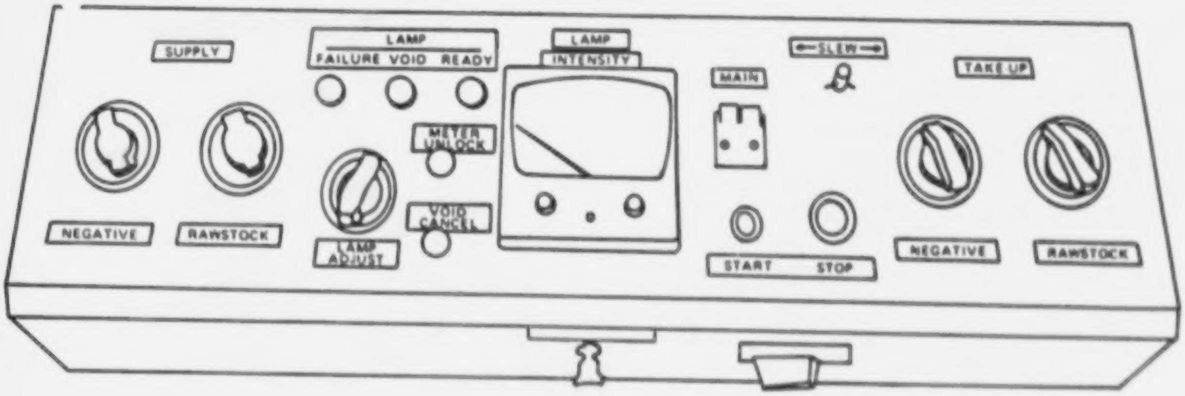

SUPPLY
LAMP
FAILURE VOID READY
LAMP
INTENSITY
MAIN
←SLEW→
TAKE UP
METER UNLOCK
VOID CANCEL
NEGATIVE
RAWSTOCK
LAMP ADJUST
START
STOP
NEGATIVE
RAWSTOCK
27843

Figure 8-3. Niagara printer control panel.

Exercises (505):

1. List the tasks that must be performed before operating the Niagara printer.

2. What is the duration of the lamp warmup period?

3. Why is the lamp warmup period necessary?

506. Select the tasks that must be performed during startup of Cayuga printer.

The Cayuga Printer. The Cayuga printer, like the Niagara printer, is a high-resolution low-distortion printer designed to produce duplicate films in continuous rolls at an operating speed of 100 feet-per-minute. This printer can also accommodate lengths up to 1,000 feet of ON. It is at this point that the two printers cease being alike.

The printing operation of the Cayuga printer is controlled by two on-board computers built into the printer cabinet. The first computer is used for frame detection. It tells the second computer what frame is being printed. The second computer controls the lamp modulation so that there is continuous automatic dodging during the printing operation.

There are also two cassette tape decks located on the printer. Quality Control programs a cassette tape for each roll of film to be printed. There will be data on the tape for each frame from a roll of film.

A CRT video display keyboard control identifies the roll by punching it in on the keyboard. The program computer (second computer) reads the tape and loads the program.

Now that you have some idea about computerized printing, let's talk about the printer startup procedures:

- Lamp voltage must be on maximum before turning POWER switch ON.
- Turn POWER switch to ON position.
- As soon as lamp intensity rises, reduce the voltage. There is no warmup time required.
- Load cassette deck with the tape that is going to be printed.
- Punch roll number to be printed in on the keyboard.

The printer is now ready for the printing operation. Computerized printing is here to stay and you will be seeing more of it in the future.

Exercises (506):

1. From the following list of startup procedures, select the ones used for the Cayuga printer.

   a. Turn POWER switch to ON position.

   b. Wait 8 minutes to allow printing lamp to stabilize.

   c. Turn lamp voltage to maximum before turning POWER ON.

   d. Press lamp interlock void button.

   e. Reduce lamp voltage after lamp intensity rises.

2. What task must be performed before the POWER switch is turned ON?

507. Explain the purpose of given "Niagara" startup procedures.

Printer Setup According to Film Width. Two tasks must be performed that are dependent upon the width of the film being duplicated. These are adjustments of the spindles and support brackets and the torque control.

a. Spindles and support brackets. To set the four spindles to the desired spool width, you must displace the collar on the inboard of each spindle to release a detent pin from a locating hole in the spindle shaft. When this pin has been released from the locating hole, the shaft may be set to the proper distance to accept the spool being used—70 mm, 5 inch, etc. The collar can then be released, the detent pin will drop into the locating hole at the desired width of film to be printed.

When you adjust the four spindles to the desired width, use the scale which has been provided to measure the desired distance from the mechanism plate to the inboard flange of the spool. All four spindles should be set the same except when printing three widths of 70mm on 9.5-inch raw stock. In this case raw stock spindles (supply and takeup) should be set to the applicable 70mm position.

The outboard supports for all supply and takeup spools are spring-loaded toward the mechanism plate and can accommodate any spool size from 70 mm to 9.5 inch. Travel of each outboard support is limited by a holding clamp on one shaft. When printing large quantities of one-width film, set and tighten the clamp about an inch away from the rubber stop in the mechanism plate after a spool is placed in the spindle-support bracket. The protruding portion of this clamp must be positioned away from the spool to avoid scratching the product. When the spool is removed, the gap between the support and spindle remains just under the desired width.

b. Torque controls. After adjusting the spindles and support brackets, you must set the Variac control knobs to provide the proper torque for the supply and takeup spindles on both the negative and raw stock material. The torque for these supply and takeup drive motors must be precisely adjusted. The torque control Variacs are positioned by the knobs located on the control panel; thus, the proper controllable tension on the film to and from the printing drum will be maintained.

For the different widths of film, the Variac knobs are positioned as shown below. These are only trial settings; adjust as necessary.

		Raw Stock	*Negative*	
Film Width	*Supply*	*Takeup*	*Supply*	*Takeup*
70 mm	45	65	40	65
5 inch	45	65	45	65
6.6 inch	45	65	45	65
8 inch	45	65	45	65
9.5	50	65	45	65

Exercises (507):

1. Explain why the supply torque for both raw stock and negative material must be higher for 9.5-inch film than it is for 70-mm film.

2. Why is it necessary to adjust the spindles and support brackets?

508. Given situations that might occur during "Niagara" startup, state the effect of each situation on printer operation.

Establishing Exposure Parameters. The Niagara printer is equipped with a set of masks which are stored in the top right drawer in the printer's base. There is a mask for each width of material for which the printer has been indexed; the sizes are marked on the front edge of each mask. These include a 9.5-inch mask, a 5-inch mask, and three 70-mm masks—70-mm IN, 70-mm CTR (center), and 70-mm OUT for printing three strands on 9.5-inch rawstock.

The lamp intensity for optimum exposure is factory set, and the meter is calibrated to zero at this setting. As the lamp is being used, a deposit of mercury on the inside of the glass eventually interferes with the passage of light and cuts down the available illumination. The lamp adjust control knob, on the left, is used to slowly increase voltage to the lamp and bring illumination up to the required standard. The two knobs on the meter are set to establish the plus and minus limits of variation which can be tolerated and still give acceptable exposure.

Luminance is measured by a photocell in the lamp house and is displayed on the meter (lamp intensity) mounted on the control panel. If lamp intensity drifts out of tolerance during operation, the meter locks and the failure light goes on. When this happens, the illumination must be brought up to tolerance by rotating the lamp intensity control (lamp adjust). The meter unlock button must be pressed before the meter can be restored to zero by adjusting the printing lamp intensity knob.

At the start of operation, the printing lamp requires 8 minutes to warm up. During this time, the printer is interlocked so that it cannot operate, and the ready light is not on. However, the printer can be operated for checkout purposes by activating the control panel void button. Activating the void button unlocks the printer and lights the void indicator lamp. The void condition continues until released by the void cancel button or after the 8-minute warmup, whichever comes first. If mission material is printed during the warmup period, exposure will be inconsistent, resulting in varying densities in the duplicate.

The lamp intensity can also be controlled by the lamp voltage selector switch, which is located on the bottom surface of the control panel. This switch has three positions—low (105 volts), medium (120 volts), and high (135 volts). Since this switch changes the lamp voltage in 15-volt steps, this control should be used only when the desired intensity cannot be obtained with the lamp adjust. As stated above, the lamp adjust control is used to slowly increase or decrease the lamp voltage.

Exercises (508):

1. What influence will the mercury deposit on the inside of the exposing lamp have on exposure?

2. What action must be taken when the lamp intensity decreases to the point that it is out of tolerance during operation?

3. If printing is accomplished during the 8-minute warmup period, what effect will this have on the duplicated product?

509. Describe the operating mechanism of the Niagara in terms of the transport system and base construction.

Printer Operation. When all preoperative functions have been performed and the 8-minute delay has elapsed (green ready lamp lighted), the printer will start operating when you press the green start button. In addition to observing the green ready lamp, you should also make sure that the lamp intensity meter still reads zero. If the green lamp is lighted and the lamp intensity meter reads zero, the printer is ready for operation.

Operating mechanism. The printer is designed for accurate reproduction and is constructed to meet heavy production schedules without interruption for maintenance and adjustment. The film transport is assembled on the face of a rigid mechanism plate in the top unit, with motors, power packs, and dust collecting units mounted on the back of the plate and inclosed in a cabinet. (For safety, access doors to the rear of the cabinet are interlocked to remove all power from the cabinet components when the doors are open.)

The drawers and cabinet provided in the base are for the storage of accessory items. Locking casters provide stability during operation with the ability to move easily from the safelight area (where other printers may be in production) to a maintenance room for occasional checkout in white light. Regulation of the power supply insures constant lamp intensity. The mechanical and electrical subassemblies are designed for ease of replacement.

Exercises (509):

1. Describe the makeup of the Niagara transport system.

2. Briefly explain how the base of the Niagara is constructed.

510. Given malfunctions during Niagara operation, determine the cause and state the effect on the quality of the printed material.

Operation. The actual operation of the Niagara consists of four functions. These are starting the printer, stopping the printer, slewing or rewinding the material, and three-strand printing.

a. Starting. To start printer operation, you must depress the start button. The printer will not start moving the negative and raw stock materials immediately since there is a 5-second delay before printing operation. This 5-second delay is to allow the torque motors time to take up the slack. After this 5-second delay, the dark shutter opens, the drive motor starts, and the printing operation begins.

As you know, good tracking must exist at all times during printing. The negative and raw stock materials should track properly if the spring-loaded collars are properly positioned on their respective spindles. However, a tracking problem may develop because of improperly made film splices. Therefore, the splices made in a length of film should be kept to a minimum. When splices are necessary, they must be well aligned.

b. Stopping. While printing, you may find it necessary to stop operation momentarily. To do this, depress the red stop button. When the stop button is depressed, the torqued motors do not deenergize immediately. As with starting operation, there must be a delay when stopping operation to prevent film slack from developing (or film spilling over) because of inertia. If slack develops, the film could be damaged. Thus, the torque motors are energized for 6 seconds after the stop button is depressed.

c. Slewing. It is possible to slew the negative with this printer. The negative can be slewed either to the supply spool or to the takeup spool by using the slew switch provided. This arrangement permits rapid movement of the negative to selected areas for printing. Remember, the original film must not be threaded around the printing drum during slewing.

d. Three-strand printing. For more efficient processing of the exposed raw stock, it is sometimes desirable to print three widths of 70-mm negative on a single width of 9.5-inch raw stock. In this manner, only one length of raw stock needs to be developed in an automatic processor instead of three separate lengths of 70-mm material, each of which would be as long as the 9.5-inch material.

To expose three equally long strands of 70-mm negative on one width of 9.5-inch raw stock, insert the 70-mm OUT mask into the lamp housing. After adjusting the negative supply and takeup spindles to the 70-mm outboard position, and adjusting the raw stock supply, take spindles to the 9.5-inch position, thread the raw stock supply and negative supply through the printer. When the printer has been properly threaded, depress the start button to print the outboard copy.

After printing the outboard copy, print the inboard copy by removing the 9.5-inch raw stock (which has a 70-mm exposure on its outboard portion) from the takeup bracket and place it on the raw stock supply spindle. The exposed strip is now in the inboard position (without rewinding or changing spindle positions). By merely threading the printer and starting the printer operation, the other outboard copy is printed.

To make the center exposure, transfer the 9.5-inch raw stock, which is now exposed on its two outer portions, from the takeup bracket to the supply bracket. Then replace the 70-mm OUT mask in the lamp housing with the one marked "70-mm CTR" (center). When you have adjusted the negative supply and takeup spindles to the 70-mm center position, the center portion of the 9.5-inch raw stock can be exposed by threading the negative and raw stock and starting the printer operation.

All three strands of 70-mm negative are now printed on one continuous strip of 9.5-inch raw stock. The 9.5-inch raw stock is removed from the raw stock takeup spindle for processing, slitting, and trimming.

Exercises (510):

1. A splice passes through the Niagara during printing and the material mistracks. Why would this happen?

2. The torque motor on the raw stock supply mechanism is not operating properly. What is likely to happen in this situation when the printer is stopped?

3. What will be the result of slewing the original film while it is still threaded around the printing drum?

8-6. Printer Shutdown and Maintenance

After all printing has been completed, shutdown of the Niagara must be performed.

511. Given examples of improperly conducted Niagara shutdown procedures, state the probable effect of these procedures on the printer or subsequent printing runs.

One of the most important features of the Niagara is that it is uncomplicated in its operation. This is true also for its shutdown procedures. The first shutdown consideration is to stop the operation of the printer transport. In reality, this task can be accomplished in any one of three ways. These are (1) depressing the stop button, (2) disengaging the pressure roller from the printing drum, and (3) turning the main power switch to OFF. Only the first is recommended. Otherwise, the torque motors are not energized for the required 6 seconds. Once the printer transport has been stopped, shutdown consists simply of turning the main power switch off. However, you must remember that if the main power switch is turned off and then on again immediately, an approximate 8-minute cooling period will elapse before the printing lamp can restart. Then an 8-minute lamp stabilization period is required before printing can take place. It is recommended that all required printing be accomplished before the main power is turned off. Otherwise, the 16-minute delay before the printer is ready for use again could prove to be the cause of mission failure when the time of production is important.

Other tasks should be accomplished, but these are largely preventive maintenance functions and are discussed in a later section of this chapter.

Exercises (511):

1. The Niagara transport was stopped by switching the main power switch to OFF. What effect might this have on the material on the printer?

2. Why is it recommended that all printing be accomplished before the main power switch is depressed?

512. Given a troubleshooting table, identify the trouble for specified unacceptable Niagara operating conditions.

Niagara Troubleshooting. Troubles may be encountered during printer operation. To preclude work stoppage, the operator should be familiar with the printer troubleshooting table.

Mechanical troubleshooting. The most common printer troubles, probable causes for each listed trouble, and the suggested corrective action to take for each trouble are listed in table 8-1.

Exercises (512):

1. Using table 8-1, identify the trouble that could result from the following printer conditions:

   a. Doors on rear of top cabinet are not closed.

   b. Printing lamp is burned out.

   c. Voltage regulator is not functioning.

   d. Battery failure.

513. Given a list of unacceptble material characteristics or printer operations, state the probable cause and recommend the appropriate remedy.

Effects of improper printer operation on duplicated product. Often, some improper printer operations result in the degradation of the photographic product. In most cases, these can be related directly to improperly conducted startup tasks and poor housekeeping. Following are three of the more common material-degrading causes:

(1) Unusual streaks in printed material. This degradation can be caused by several things. These are:

- Dirt on calibrated wedge.
- Nicked printing drum or rollers.
- Film threaded improperly.

Dirty film transport components.

- Lamphouse mirror(s) dirty.
- Mercury-are lamp orientation incorrect.

(2) Loss of resolution. Decreased resolution in the duplicated material is usually the result of material slippage. This slippage can occur during Niagara operation as a result of:

- Film tension not properly adjusted.
- Pressure roller out of adjustment.

(3) Material mistracking. The three most common causes of material mistracking are:

- Spindle heads located at different distances from the mechanism plate.
- Idler rollers binding.
- Pressure roller not contacting the film properly.

In the preceding paragraphs, we briefly outlined those factors that can lead to decreased duplicate image quality.

TABLE 8-1

TROUBLESHOOTING TABLE

(Niagara)

TROUBLE	PROBABLE CAUSE	REMEDY
1. Calibration dial is out of calibration	a. Dial plate was not properly aligned when calibrated wedge was removed for cleaning or other maintenance.	a. Align dial plate
2. Operator receives shock when touching metal parts of printer.	a. Loose ground connection of power cable	a. Check and secure connection of power cable green wire to printer.
	b. Faulty connector on power cable	b. Replace connector.
3. Eight minutes after turning main switch on, lamp ready light fails to glow.	a. Power cable not plugged into receptacle.	a. Connect power cable.
	b. Faulty connector on power cable.	b. Replace connector.
	c. Faulty power cable.	c. Replace power cable.
	d. Doors on rear of top cabinet not closed.	d. Close both doors.
	e. Mercury-Tungsten switch in Tungsten position.	e. Switch to mercury position.
	f. Connector not mated properly to receptable inside lamp house.	f. Mate connector properly.
	g. Printing lamp burned out.	g. Replace printing lamp.
	h. Tungsten lamp in lamp house	h. Remove and install mercury.
4. Eight minutes after turning main switch on, lamp ready light glows, lamp failure light glows, lamp intensity meter pointer is jammed against left side. Printer starts when start button is pressed.	a. Glass envelop of printer lamp has lamp has become clouded.	a. Replace printing lamp.
	b. Solar cell assembly defective.	b. Replace solar cell.
5. Eight minutes after turning main switch on, lamp ready lamp glows, but printer fails to start.	a. Pressure roller assembly not in contact with printing drum.	a. Position pressure roller assembly to contact printing drum.
6. During operation, printer shuts down. No pilot light glows.	a. Printing lamp burned out.	a. Replace printing lamp.
	b. Voltage regulator not functioning.	b. Check fuses.
7. Lamp intensity meter indicator hits a stop but lamp failure light does not glow.	a. Lamp failure light bulb burned out.	a. Replace light bulb.
8. Lamp ready light not glowing during printing operation.	a. Lamp ready light burned out.	a. Replace bulb.
9. No pressure roller alarm can be heard when main switch is off and pressure roller is down.	a. Failure of battery.	a. Replace battery.

The methods by which these can be corrected are, in most cases, self-evident. However, the suggested corrective actions for each are listed in the TO for the Niagara Printer.

Exercises (513):

1. List the probable causes for the following unacceptable material conditions and suggest what action should be taken to correct each condition:

   a. Streaks in the printed material.

   b. Loss of resolution.

   c. Mistracking of material.

514. From a list of Niagara Printer cleaning tasks, explain what effect the neglect of these tasks will have on the photographic quality.

Preventive Maintenance for the Niagara Printer. With the Niagara Printer, you should follow the same good housekeeping procedures used for other precision photographic equipment. Keep the printer clean at all times, and, make sure that the printing drum and guide rollers are kept extremely clean.

Cleaning. The dust and static removal units and the inside of the lamp housing must be kept clean. You should periodically inspect the brushes and inductors on the removal units incorporated in the film drive system for any unusual buildup of dust or dirt. This is particularly necessary since dust or dirt buildup can cause the dust and static eliminating inductor to arc across, thus damaging the unit and decreasing its effectiveness. To dislodge dirt from the brushes, you can pass a heavy piece of cardboard through the cleaning station several times. Then use a vacuum cleaner to pick up the loose particles.

When you are cleaning the dust and static brushes and inductors, the printer should be turned on but unthreaded so that the blower can be used to exhaust the dirt into the litter bag. For removing the accumulation of dust around the points of the static eliminating inductor, you should use a toothbrush. Always be sure that this dust is removed. As you use the toothbrush to remove the dust, take extra care not to bend or break the inductor points—these are small, exposed pieces of wire.

In addition to cleaning the static removal units, you should periodically remove the lamp housing cover and dust (or vacuum clean) all parts. If dust is allowed to accumulate, it can affect the light intensity of the printing lamp as well as feedback to the solar cell.

CAUTION: *If the printing lamp is lighted for any reason without the lamp housing cover in place, do not expose your eyes to the ultraviolet light by looking at the lamp. As a safety precaution, you should wear yellow filter goggles when checking the light source.*

While cleaning the interior of the lamp housing, you should also clean the variable neutral density wedge. You should use extreme care while handling the wedge because scratches on the filter will cause streaks in the photographic output.

To clean the variable density wedge, you must remove the access plate on the left side of the lamp housing. Before removing the wedge, turn the adjusting knob dial to its extreme counterclockwise position. Make sure that an indicating mark has been inscribed on the dial for aligning the index point with the dial when you are ready to replace the wedge. If a mark has been inscribed, turn the dial knob clockwise with the right hand and hold the variable density wedge with the left hand. When the wedge reaches the end of the track, remove and clean the wedge with a lens cleaner solution and a clean lint-free cloth.

When replacing the wedge, you should reverse the above procedure. After it has been replaced, align the wedge and adjusting dial knob as follows:

a. Turn the dial knob counterclockwise until it stops.

b. Loosen the three clamping screws on the dial plate.

c. Turn the dial plate until the index point above the knob on the front of the lamp housing and the inscribed mark beyond 1.0 on the dial are lined up.

d. Tighten the three screws; this completes the calibration.

Cleaning schedule. To insure that the printer is maintained in a clean condition, you should establish a daily, weekly, and monthly cleaning schedule similar to the following:

a. Dust printer exterior daily—if printer is used on a 24-hour basis, it should be cleaned between operations.

b. Examine all spindle bearings daily for freedom of rotation as well as cleanliness.

c. Examine all guide roller surfaces and the printing drum surface daily for cleanliness and for nicks—all nicks should be polished flush with the surface to eliminate scratching and marring the negative and raw stock materials.

d. Clean the camel's-hair brushes on the negative dust and static removal unit daily as previously described.

e. Clean the edge of the raw stock dust and static removal unit weekly and remove any buildup which has formed.

f. Remove the litter bag monthly (or oftener) and empty out the dust or dirt that has collected.

g. Remove the covers on the raw stock dust and static unit monthly (or as required) and remove any accumulation of dust as previously explained.

h. Remove lamp housing cover monthly (or as required) and dust all parts as previously explained.

i. Remove the variable density wedge monthly (or as required) and clean as prescribed previously.

j. Open hinged rear doors and inspect air manifold filters monthly (or as required). If the top one is dirty, you should discard both filters and replace them with new filters.

Exercises (514):

1. Indicate what effect on the photographic product will result if the following cleaning tasks are not performed:

   a. Cleaning the inside of the lamp housing.

   b. Cleaning the variable neutral density wedge.

   c. Emptying the vacuum bag.

   d. Cleaning the brushes and inductors on the dust and static removal units.

   e. Cleaning the roller and printing drum surfaces.

515. State how failure to conduct certain inspection functions will affect Niagara operations.

Inspection. Although most inspection checks are performed while printer components are being cleaned, there is one inspection that should be performed periodically. This involves checking the warning buzzer battery. To check the battery condition, place the pressure roller positioning lever in the vertical (or printing) position with the main power switch in its OFF position. If the warning buzzer does not sound, this 6-volt battery must be replaced.

As stated previously, tracking should be excellent if a minimum number of splices are used. However, if the spindles are not correctly adjusted or if the pressure roller does not have the correct tension, you may have a tracking problem, and the condition should be reported to maintenance.

The final important inspection pertains to the printing lamp. Whenever the lamp has to be removed and replaced because of insufficient intensity, you must place the lamp properly in the lamp socket to prevent obstructing the illumination in the printing area. When you screw a new printing lamp into the socket, the lamp must be oriented so that the exhaust tip and the starting wire are up. In addition, the supporting posts for the inner quartz envelop should be at a 45° angle with the lamp house base.

Any maintenance, other than that described in the previous paragraphs, should be performed by qualified maintenance personnel. Your major contribution is keeping this equipment clean. Any malfunctions or potential troubles must be immediately reported. You, as an operator, are the first to notice improper operation. Also, be sure that you know when scheduled maintenance is to be performed since your equipment will be out of service.

Exercises (515):

1. Explain what might result if the following inspections are not performed.

   a. Checking the warning buzzer battery.

   b. Pressure roller tension.

   c. Placement of exposing lamp.

8-7. Electronic Dodging Printer Operations

The electronic dodging method is well suited to produce dodged prints while still maintaining adequate production. The SP 10/70B and Mark II R5A printers use this dodging method. Let's look at their operating principles.

516. Identify the printer component that is responsible for certain printer functions.

SP 10/70B Contact Printer. The SP 10/70B printer consists of an enameled cabinet upon which is mounted a transport system, cassette, and photomultiplier box. The interior of the cabinet houses an electronic chassis, a power supply chassis, a main drive motor and control chassis, a cathode-ray tube (CRT), a lens and bellows, junction box assembly, and transparency supply and takeup spools. All cabinet components are accessible when the access covers are removed. Mechanical and electronic controls, switches, and associated indicator lamps are located conveniently on the two control panels on the front of the cabinet. A transparency viewing table is set flush in the top of the cabinet.

Functional Description. Functionally, the SP 10/70B printer incorporates a transport system, printing light source, exposure level control circuits, automatic dodging circuits, regulated power supplies, and is capable of handling material 70 mm to 9.5-inches. The lens supplied with the SP 10/70B has a resolution capability of reproducing 200 lines per millimeter. A functional description of the SP 10/70B printer is given in the paragraphs that follow.

Transport system. The elements of the transport system are shown in figure 8-4. The transport mechanism has two modes of operation: REWIND and PRINTING. The printing system operates only when the printing stage is in the lowered and locked position.

During printing, the transparency and the printing material are drawn from their respective supply spools, driven right in a horizontal plane through the printing stage with their emulsion sides in intimate contact, and then

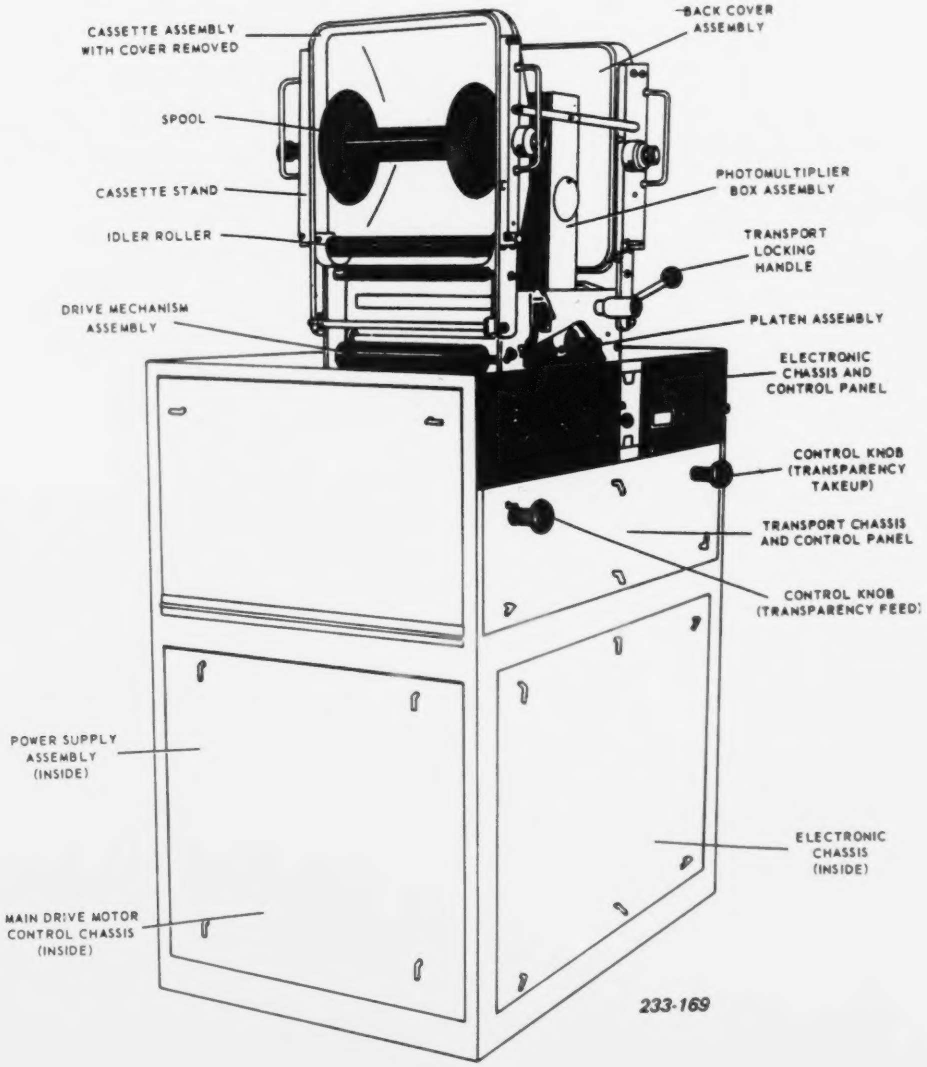

CASSETTE ASSEMBLY WITH COVER REMOVED
SPOOL
CASSETTE STAND
IDLER ROLLER
DRIVE MECHANISM ASSEMBLY
BACK COVER ASSEMBLY
PHOTOMULTIPLIER BOX ASSEMBLY
TRANSPORT LOCKING HANDLE
PLATEN ASSEMBLY
ELECTRONIC CHASSIS AND CONTROL PANEL
CONTROL KNOB (TRANSPARENCY TAKEUP)
TRANSPORT CHASSIS AND CONTROL PANEL
CONTROL KNOB (TRANSPARENCY FEED)
POWER SUPPLY ASSEMBLY (INSIDE)
ELECTRONIC CHASSIS (INSIDE)
MAIN DRIVE MOTOR CONTROL CHASSIS (INSIDE)
233-169

Figure 8–4. SP 10/70B continuous contact printer.

directed to their respective takeup spools. The transparency and printing materials are maintained in an almost flat plane during transport.

Resolution of the duplicate can be drastically reduced by improper Y-scale (direction of material travel) adjustment. This decreased resolution results from the improper positioning of the compensating adjustment provided. Three positions are available. These are for (film), SW (single weight paper), and DW (double weight paper), and each should be used in conjunction with the appropriate material.

Four rubber rollers are located at strategic points where the transparency and printing material experience sharp changes in direction. On these rollers, radial slits are cut at 45° angles inclined toward the center of the roller. As a result of differential friction, these slits force the transparency and printing material to track along the centerline of the rollers, thereby insuring correct registration of prints with respect to the printing material.

The drive mechanism is located in the printing area and contains a drive roller and a drag roller (fig. 8-5). The drive roller is located on the takeup side of the main frame (to the right of the printing aperture) and the drag roller is located on the supply side of the main frame (to the left of the printing aperture).

The drive roller is driven by a 1/4 horsepower variable-speed motor and reduction pulley system. The speed of the motor shaft is controlled by adjustment of its DC input voltage, derived from a magnetic amplifier in the main drive motor control chassis. This manual adjustment, from 5 to 60 fpm, is made by rotating the printing speed control, located on the transport control panel. The drive roller rotates in a clockwise direction when viewed from the front of the printer, and provides forward motion to the transparency and printing materials.

Two rubber rollers located on the printing stage are positioned directly above the drive and drag rollers when the printing stage is lowered and locked. These rollers exert pressure on the transparency and printing material during the printing mode of operation. This pressure is sufficient to provide emulsion-to-emulsion contact, and causes these rollers to rotate with the drive and drag rollers. The braking action of the drag rollers places enough tension on the materials as they traverse the small steel rollers at the printing aperture to insure excellent printing resolution during exposure. Each controlled exposure takes place as a frame passes over the printing aperture, which is a narrow slit positioned at right angles to the direction of transport.

The printing platen is a free-turning lucite roller located on the printing stage and positioned directly above the printing aperture. This roller presses against the nonemulsion side of the printing material and assists in maintaining intimate contact between the emulsion surfaces of the printing material and transparency. Since the lucite roller is transparent, light passing through the transparency and the printing material from the scanning spot is admitted readily for view by two photomultiplier tubes.

The printing stage can be raised above the printing aperture by moving the locking handle to the right, thereby braking the emulsion-to-emulsion contact between the

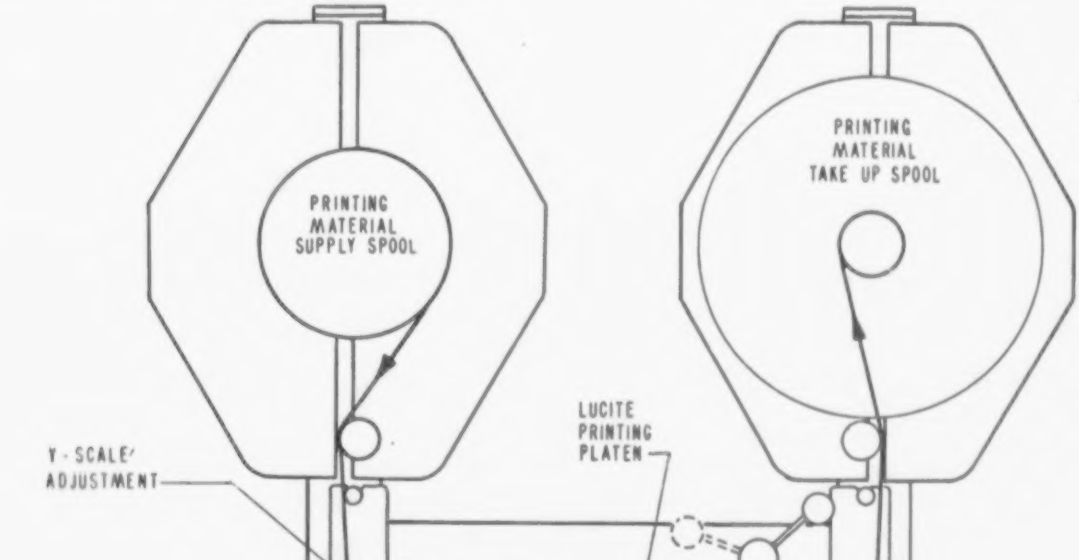

PRINTING MATERIAL SUPPLY SPOOL
PRINTING MATERIAL TAKE UP SPOOL
LUCITE PRINTING PLATEN
Y-SCALE' ADJUSTMENT
F
DW
SW
PRINTING STAGE
EMULSION SIDE
VIEWING TABLE
DRIVE ROLLER
DRAG ROLLER
PRINTING APERTURE
MASK HOLDER
MASK
TRANSPARENCY SUPPLY SPOOL
AUTO-TORQUE RESISTOR
TRANSPARENCY TAKE UP SPOOL
TORQUE MOTORS
233-170

Figure 8-5. Transport system of the SP 10/70B printer.

transparency and printing material. This procedure simplifies the threading operation and accommodates the rewind operation, permitting the transparency to be shuttled back and forth between spools to omit printing of some frames, or to enable duplicate printing of a group of frames. An electrical interlock prevents the main drive system and printing light source from being energized unless the printing stage is lowered and locked.

The transparency supply and takeup spools are driven by individual torque motors, which are supplied with variable voltages to compensate for the changing diameters of material on the two spools.

The transparency supply torque motor is energized to rotate clockwise, but is rotated counterclockwise by the material drawn from the supply spool. In attempting to rotate clockwise, it maintains tension on the transparency between the supply spool and drag rollers.

The transparency takeup torque motor rotates the takeup spool in a counterclockwise direction, and the torque of the motor is varied by the action of an auto-torque resistor which samples the changing diameter of material on the transparency supply spool. When the supply spool is full, a reduced voltage is fed to the takeup torque motor. This voltage is increased gradually by rotation of the auto-torque resistor arm as the supply empties and the takeup spool fills. Conversely, the supply torque motor receives maximum voltage when the supply spool is full, and a diminishing voltage as the supply spool empties and the takeup spool fills. During the rewind mode of operation (printing stage raised), the auto-torque resistor function is replaced by that of the transparency rewind speed and direction control. Rotating this control counterclockwise increases the torque of the supply motor and decreases the torque of the takeup motor, thereby rewinding the transparency onto the supply spool. Conversely, rotating the control clockwise increases the torque of the supply motor, enabling the transfer of the transparency to the takeup spool without printing.

During operation, each spool is retained in position by an undriven spring-loaded spool-holder spindle which is provided with an external cam-type restrainer. This enables the spring pressure to be removed while loading or unloading materials. The SP 10/70B will hold 500 feet of print material and 400 feet of transparency.

Printing light source. A 10-inch-diameter, aluminized cathode-ray tube provides the printing light source in the strip printer. The cathode-ray tube, operating in conjunction with the projection lens, produces a scanning exposure which is intensity modulated by signals from the dodging and exposure level control photomultiplier tubes. As shown in the block diagram (fig. 8-6), scanning in the X-direction, or at right angles to the motion of the transparency and printing material, is provided by an electromagnetic deflection yoke controlled by an X-scan generator. The scan in the Y-direction is produced by the motion of the materials as they pass over the printing aperture.

The X-scan generator consists of circuits located in the electronic chassis. A symmetrical, 700-cps square wave generated by a free-running multivibrator is converted to a triangular wave by a feedback integrator which feeds a cathode-coupled difference amplifier. The push-pull output of the difference amplifier drives a DC coupled bridge amplifier which supplies the current required for operation of the X-deflection yoke. The repetition rate of the triangular current waveform is 700 cps or approximately 1,400 sweeps per second. The scanning rate is sufficiently high in terms of transport speed and spot size to eliminate any evidence of scan lines in the prints.

Automatic exposure level control. The actual exposure level depends not only upon the speed of the printing emulsion but also upon the combination of average brightness level and transport speed. Control of the average cathode-ray tube brightness in the transport direction (Y-axis) is accomplished by an exposure level photomultiplier tube, which is equipped with a lens and aperture plate assembly, shown in the block diagram (fig. 8-6), to restrict the field of view in the X-direction to a 1½-inch region at the center of the printing aperture. The photomultiplier tube measures spot brightness during a part of each scanning line. The anode current output is amplitude modulated by variations in transmission density. The ripple component is removed from this signal; and a varying, negative DC voltage is developed and fed through the DC coupled cathode follower output stage to the grid of the cathode-ray tube to control the beam current continuously. This control maintains a constant average brightness which, in turn, produces a uniform exposure over the full length of the printing material.

When the frames of the transparency are dense, the anode current is decreased, reducing cathode-ray tube bias and increasing spot brightness. Conversely, when the frames of the transparency are less dense, the spot brightness is decreased. The degree of exposure control is adjustable by varying the operating voltage for the photomultiplier tube from the negative 1,000-volt supply. An exposure level meter registers the average anode current and provides a continuance of brightness control at the printing stage. Maximum printing efficiency is obtained by causing the cathode-ray tube to reach peak brightness while scanning the densest group of transparencies within a given roll. All transparencies which are less dense will be correctly exposed because the brightness level at the emulsion will be held substantially constant by the action of the exposure control negative feedback loop. This condition is achieved operationally by adjustment of the END POINT control.

Automatic dodging. Light originating at the scanning spot on the faceplate of the cathode-ray tube, shown in the block diagram (fig. 8-6), is projected by a conventional 6-inch focal length lens through the transparency and printing material. A portion of this light, diffused after it passes through the materials, is intercepted by a 10-dynode, dodging photomultiplier tube. This tube views the entire length (X-direction) of the cathode-ray tube scan in the printing aperture and monitors the transmission density of the transparency continuously at all points in the printing stage.

Variations in density of the transparency produce proportional variations in incident light intensity at the photomultiplier tube and control and the magnitude of currents derived from photocathode emission. Dense areas in the transparency are represented by smaller currents and thin areas are represented by larger currents. The actual

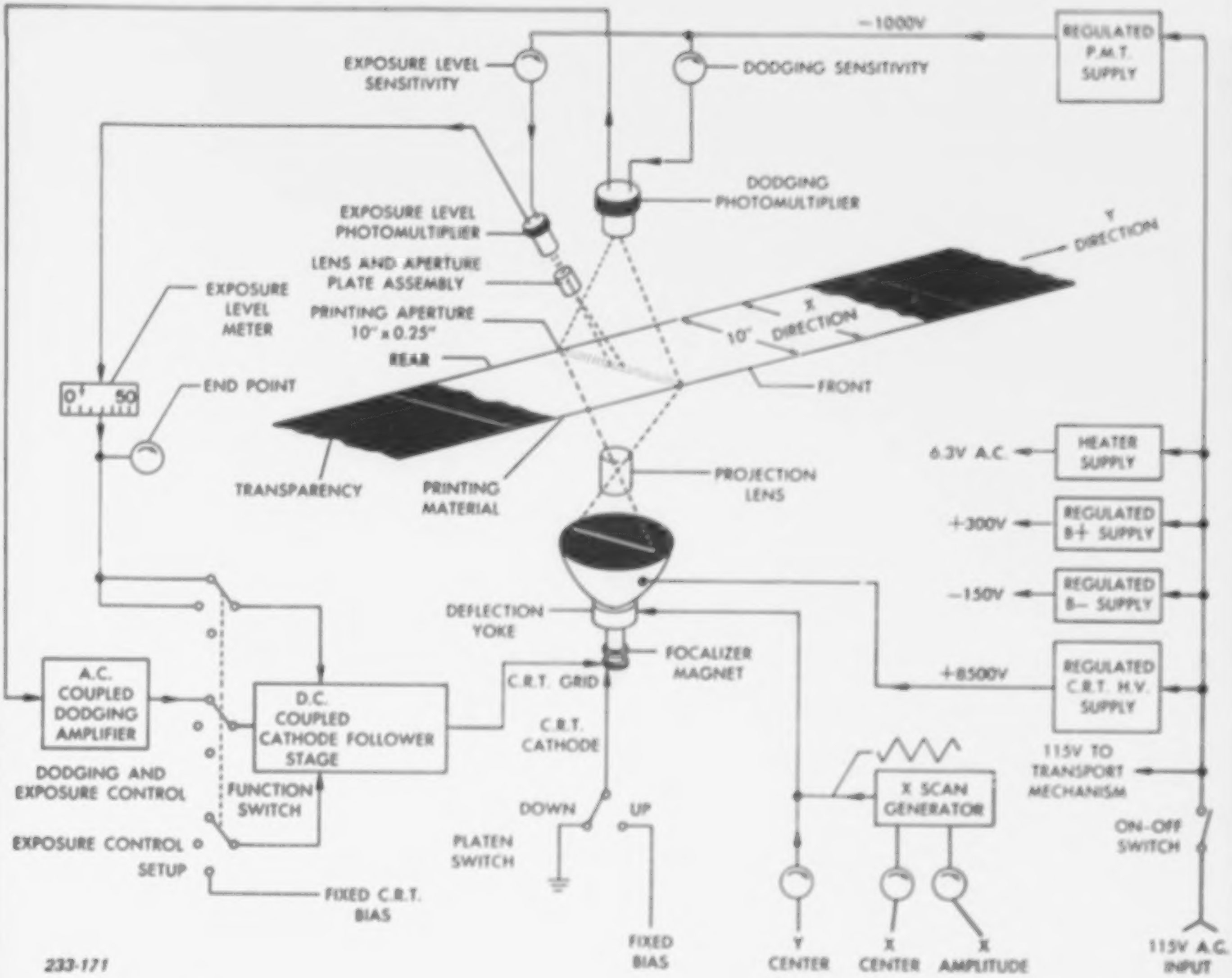

−1000V
REGULATED P.M.T. SUPPLY
EXPOSURE LEVEL SENSITIVITY
DODGING SENSITIVITY
DODGING PHOTOMULTIPLIER
EXPOSURE LEVEL PHOTOMULTIPLIER
Y DIRECTION
LENS AND APERTURE PLATE ASSEMBLY
EXPOSURE LEVEL METER
PRINTING APERTURE 10" x 0.25"
X DIRECTION
10"
REAR
FRONT
0
50
END POINT
TRANSPARENCY
PRINTING MATERIAL
PROJECTION LENS
6.3V A.C.
HEATER SUPPLY
+300V
REGULATED B+ SUPPLY
−150V
REGULATED B− SUPPLY
DEFLECTION YOKE
FOCALIZER MAGNET
+8500V
REGULATED C.R.T. H.V. SUPPLY
A.C. COUPLED DODGING AMPLIFIER
D.C. COUPLED CATHODE FOLLOWER STAGE
C.R.T. GRID
C.R.T. CATHODE
115V TO TRANSPORT MECHANISM
X SCAN GENERATOR
DODGING AND EXPOSURE CONTROL
FUNCTION SWITCH
EXPOSURE CONTROL
SETUP
DOWN
UP
PLATEN SWITCH
ON-OFF SWITCH
FIXED C.R.T. BIAS
FIXED BIAS
Y CENTER
X CENTER
X AMPLITUDE
115V A.C. INPUT
233-171

Figure 8-6. SP 10/70B block diagram.

currents obtained are subjected to considerable amplification by action of the 10 dynodes. The degrees of dodging is adjustable by varying the voltage applied to the dynode voltage divider network from the regulated negative 1,000-volt supply. The dynode currents obtained are AC amplified by an AC coupled, dodging amplifier. The cathode follower output stage provides a low-impedance drive for the AC dodging signals fed back to the cathode-ray tube grid and for the DC coupled exposure control voltage, which constitutes the working bias for the cathode-ray tube during printing. The response of the feedback loop is fast compared to the scanning rate, and enables the dodging signals to provide instantaneous, continuous control of cathode-ray tube brightness. The scanning spot is brightened for dense transparency areas and is dimmed for thin transparency areas.

Control Panel Description. Most of the controls on the SP 10/70B are located on two control panels at the front of the machine (figs. 8-7 and 8-8A), or at the top of the photomultiplier box. The controls for the operation of the transport system are grouped at the left side of the machine on the transport control panel and the controls for exposure regulation are grouped on the right side of the machine on the electronic control panel. The functions of each control are given below.

Power switch. When the power switch is on, 115-volts AC potential is applied to the printer circuits. When the switch is off, no power reaches the printer.

Viewing table switch. This switch operates a red safelight viewing table in the transport system. The table precedes the printing area so that transparencies may be viewed before they are printed.

Printing start switch (with indicator light). After the printing stage has been lowered and locked with its handle, this switch is pressed and released to start the printing mode of operation. When the printing stage is raised, the machine stops printing. (During printing, the indicator light glows.)

Printing speed control. This control consists of a dial that is calibrated in arbitrary units from 1 to 10. Transport speed is increased gradually as the dial is rotated in a clockwise direction.

Transparency rewind press switch (with indicator light). When pressed and held down, this switch applies power to the required circuits and the indicator light glows.

Transparency rewind speed and direction control. While the transparency rewind press switch is depressed, this switch is rotated to control the speed and direction of the transparency motion.

Function switch (with indicator light). This switch operates when the printing stage is lowered and locked. When the switch is set on SU (set up), the CRT is operating at constant brightness to facilitate centering the projection scan in the printing aperture. (The exposure level meter and the indicator light do not operate at this time.) When the switch is set on EC (exposure control), exposure is controlled from frame to frame, but there is no dodging within a frame. This position is used when duplicating a roll of transparencies which has already been dodged once. Redodging would produce an overly flat print. (The exposure level meter is operating at this time, but the indicator lamp is not.)

When the switch is set on EC&D (exposure control and dodging), exposure control from frame to frame, and dodging within a frame, are accomplished. (The indicator light glows at this time.)

CAUTION: Unless the function switch is in the SU position, the room's light should be off when the machine is operating. Failure to turn the lights off will result in damage to the PMTs.

X center control. Rotating this control shifts the projected scan of the CRT in the X direction (lengthwise in the aperture) without altering the length of the scan.

X amplitude control. Rotating this control changes the CRT scan length in X direction.

Y center control. Rotating this control shifts the projected scan of the CRT widthwise in the aperture (in the direction of the transport motion) without altering the length of the scan.

WARNING: AT NO TIME SHOULD THE X AMPLITUDE AT THE CRT FACEPLATE BE LESS THAN 8 INCHES. THIS COULD CAUSE PHOSPHOR BURNS ON THE CRT.

Exposure level meter. This meter, calibrated in microamperes, indicates the light intensity at the printing aperture during EC and EC&D functions.

End point control. This control adjusts the automatic exposure level circuit so that the CRT reaches maximum average brightness while scanning the densest transparencies of a roll. Clockwise rotation increases the light intensity and the reading level on the exposure level meter.

Controls on the PMT Box. Discussed below are the dodging control and the exposure control.

Dodging control. This control adjusts the sensitivity of the dodging PMT. If too much dodging is being obtained, lower the PMT sensitivity by turning the control counterclockwise.

Exposure control. This control adjusts the sensitivity of the exposure control PMT. If increased density in the optical path is apparent (due to printing with relatively opaque materials), rotate this control clockwise to increase sensitivity.

Accessories. Among the printer accessories are masks, adapters, and lens.

Masks. The printer is installed normally with green masks positioned for printing 9⅜ inch transparencies. Alternate accessories are available to permit working with 5¼ inches and 70 millimeter materials. These accessories consist of masks, roll paper core adapters, film spool adapters, and a +2 Porta lens.

Strips of transparent, colored acetate are satisfactory for mask material. However, neutral density strips may be used if desired, or any other material that has an apparent density equal to the average density of the transparency being printed. After the masks have been correctly positioned in the mask holder, pieces of transparent, pressure-sensitive tape may be used to secure them in place. The mask aperture is a flat metal bar with an elongated slot in the center and with undercut grooves along the edges for supporting the mask material. Access to the mask aperture is gained by removing the small cover plate located

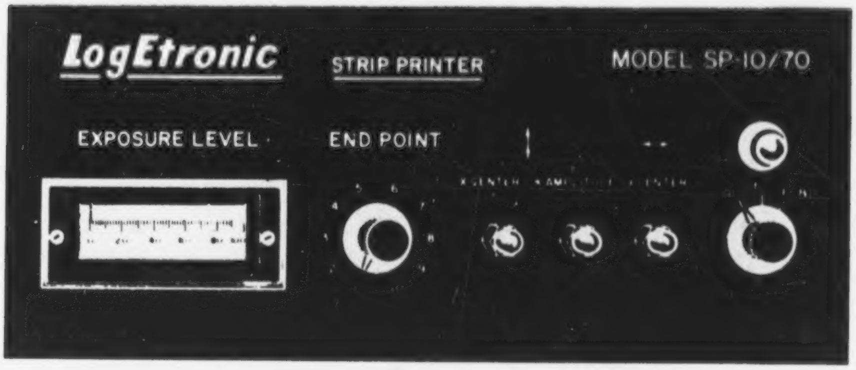


Figure 8-7. Electronic control panel.

between the two control panels. The mask aperture is removed from the holder by sliding the aperture out along the mounting track. The aperture has an adjustable stop, and a detent at the far end which correctly positions and locks the aperture in place.

Adapters. Adapters are supplied for roll paper cardboard cores that have an inside diameter of 2½ inches or wood cores that have a 2-inch square hole. An adapter shaft fitted at one end with a flange containing a square plug accommodates either type of core. Two different threaded flanges for the other end of the shaft are interchangeable. The flange with the 2-inch plug accommodates the wood core. The other flange accommodates the cardboard one.

CAUTION: The use of any spool with a core diameter of less than 2 inches is not recommended. Excessive tension may result if transparency and printing materials are drawn onto takeup spools having smaller cores (fig. 8-8B).

Film spool adapters are supplied in sets of four for both transparency and printing material supply and takeup spools. These adapters permit centering of 5¼ inch and 70 millimeter materials in the transport system.

Lens. A 2 Porta lens is supplied for use in conjunction with the 6-inch focal length projection lens when installed in the upper mounting position. This reduces the projected scan optically to the correct size for printing on 70-millimeter material.

Exercises (516):

1. Following is a list of printer functions and the component that is responsible for each function. Match each function with its proper component by placing function letters in column B in the appropriate component blanks in column A. Column b items may be used once or not at all.

Component

_____ (1) Printing speed control.
_____ (2) Transport roller.
_____ (3) Drive roller.
_____ (4) Drag roller.

Function

a. Controls the output of the photo multiplier tube.
b. Maintains tension on the transparency and the printing material.
c. Controls the variable-speed motor.
d. Maintains close contact between the transparency and the printing material.
e. Provides forward motion for the transparency and printing material.

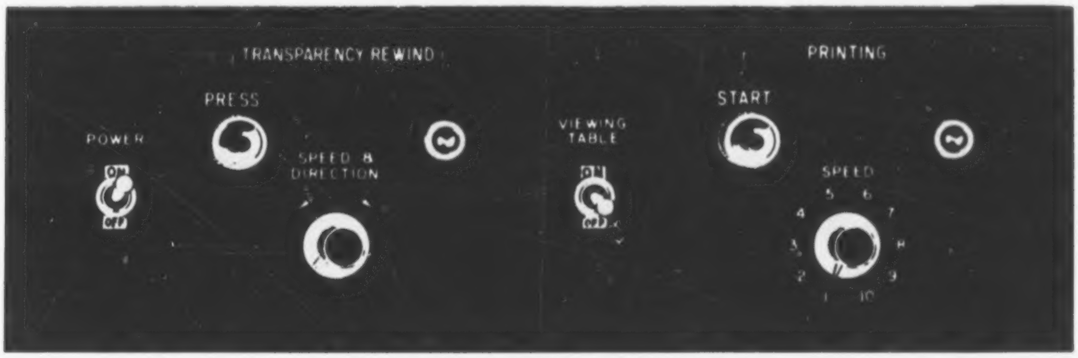


Figure 8-8A. Transport control panel.

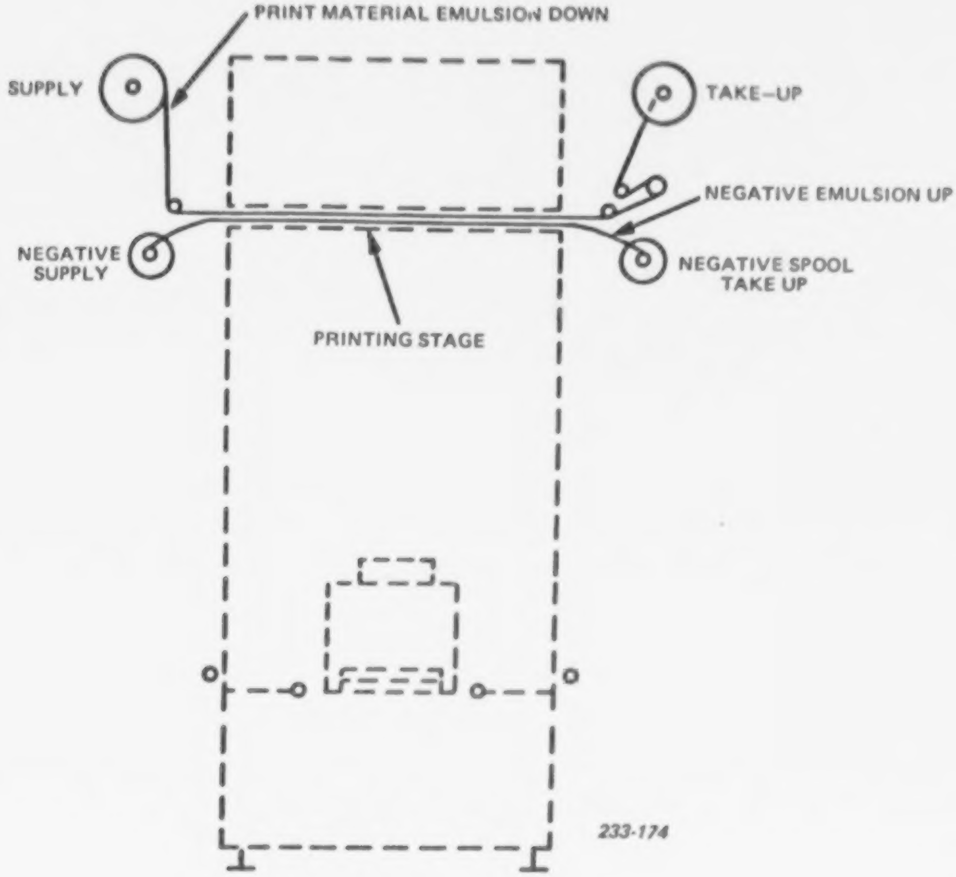


Figure 8-8B. Contact mode threading diagram.

2. What is the printing light source of the SP 10/70B printer?

8-8. Color Printer

In some cases, the printers used for color printing can be the same ones you used in your black-and-white work. Generally, printers are typed in two categories—contact and optical. These two categories remain the same in color printing. However, they are subtypes and the printers are further called additive and subtractive. Let's see what is meant by this categorization. Such a knowledge is necessary if you are to determine proper lighting.

517. Distinguish between the additive and subtractive printers.

Types of Printers. As previously stated, all color printers are classified either as an additive or subtractive type printer. The following paragraphs discuss the characteristics of each.

Additive printers. An additive system color printer is one in which the white printing light is produced by combining red, green, and blue light. Such a printer can be, or is similar to, the Model 6100C. In this printer, the initial white light is produced by a projection lamp. The light is split into a red, a blue, and a green beam by means of dichroic mirrors. Each of the three beams is then attenuated as desired to a certain amount and recombined (added together) to produce the desired illumination. A system of this kind could also employ three separate light sources of the three primary colors, eventually combined at the printing aperture.

Balanced illumination is obtained when each color (red, green, and blue) is of an amount and spectral passband that linearly exposes each film layer over the log E range of the layer. This means, for example, that a certain amount of the red light component will produce a proportional amount of cyan dye in the film. The same consideration holds true for the green light (magenta dye) and the blue light (yellow dye). To allow for adjustments in the amount of dye production, the printer must have provisions for separate and independent control of the primary color intensities. Using this means, a light intensity decrease is attained by attenuating *equal* amounts of each beam. Color correction is gained by *selectively varying* each of the three color beams to some specified amount.

Subtractive printers. A typical example of a subtractive printer is the Model J. As with the Model 6100C printer, *original illumination is supplied by a white lamp. In the* subtractive system, light *intensity* changes are made with a variable shutter, matte, neutral density filtration, etc., to attenuate the white light falling on the aperture. Color correction, to some specified amount, is provided by introducing color compensating filters in the white beam before the light falls on the aperture. The filter pack subtracts, as desired, certain amounts of red, blue, and green from the white light.

Color correction is most often made up by a *combination* of color compensating (CC) filters (yellow, cyan, and magenta). The combination produces the desired color rendition on the print by selectively subtracting proper amounts of the primary colors in the exposing light. It should be noted that CC filters show very little coloration to the eye. You can scarcely see a difference when such a filter is placed in a beam of white light. The film, however, can "see" the difference.

Exercises (517):

1. Explain how additive-type color printers produce light suitable for color printing.
2. Explain how subtractive-type printers produce light suitable for color printing.

518. Solve given problems associated with the 6100C printer.

Printer Functions. In discussing the 6100C printer, there are three printer functions that demand special emphasis. These are the optical system, the light valves and trimmers, and the program tape reader.

Optical system. The optical system consists of a single printing lamp, optical condensers, heat filters, and dichroic mirrors, as shown in figure 8-9. These components are contained in the lamphouse, vane housing, and aperture housing, together with the fader, douser, and the light valves.

The standard printing lamp supplied is a 1000-watt, 25-hour, 115- to 120-volt lamp incorporating a proximity reflector. The lamp is mounted base down in a pin-type base which is adjustable in six directions. Indicator dials are provided for lateral and rotational adjustments, and all adjustments are provided with positive locking devices.

Two primary condensers form the beam ahead of the lamp, and two heat filters are used to reduce the infrared radiation to the system. A cover glass contains the air draft within the lamphouse.

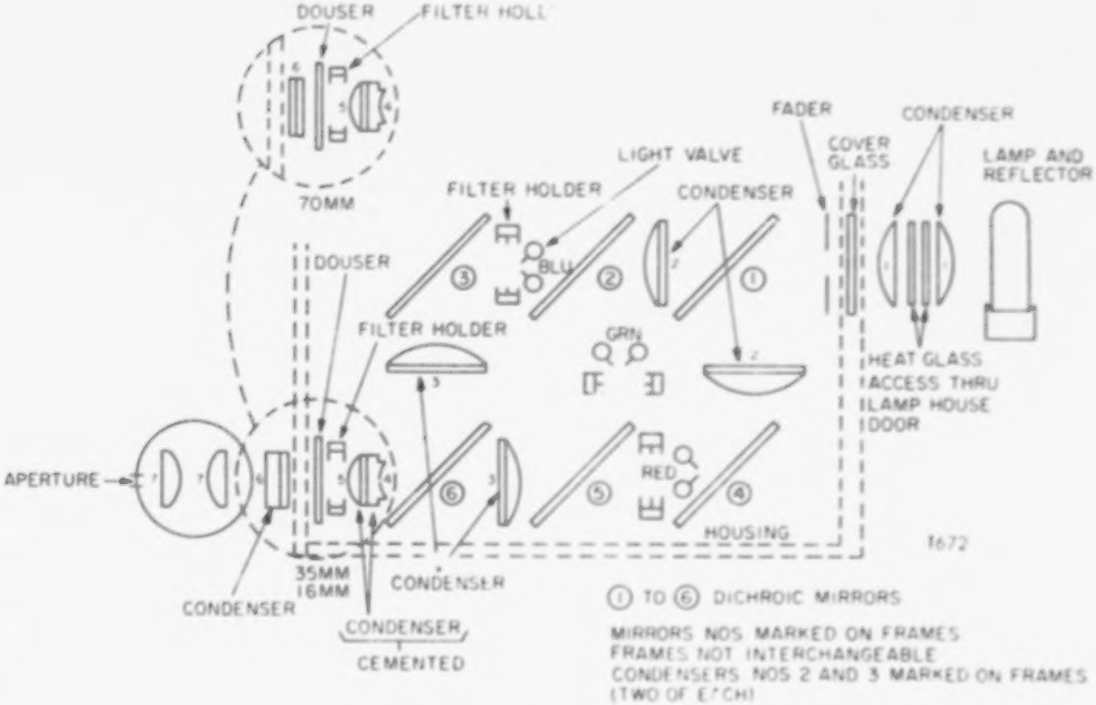

DOUSER
FILTER HOLL
6
5
4
70MM
FADER
CONDENSER
COVER GLASS
LAMP AND REFLECTOR
LIGHT VALVE
FILTER HOLDER
CONDENSER
DOUSER
③
BLU
②
2
①
FILTER HOLDER
GRN
3
2
HEAT GLASS ACCESS THRU LAMP HOUSE DOOR
APERTURE
7
7
6
5
4
⑥
3
⑤
RED
④
HOUSING
1672
35MM
16MM
CONDENSER
CONDENSER
CONDENSER
CEMENTED
① TO ⑥ DICHROIC MIRRORS
MIRRORS NOS MARKED ON FRAMES
FRAMES NOT INTERCHANGEABLE
CONDENSERS NOS 2 AND 3 MARKED ON FRAMES
(TWO OF EACH)

Figure 8-9. Model 6100C optical system.

Two fade shutters move into the light beam to effect dissolves and fades. The white light next is projected through a system of beam-splitting dichroic mirrors to produce three beams of the primary colors (red, green, and blue). Individual control of each of these beams is the automatic function of the printer.

The white light from the printing lamp is split into red, green and blue beams, having narrow bandpass characteristics to yield pure color. Their intensities are controlled individually (for color printing), and the light is then recombined to provide a specific balance of light for printing. A filter holder is provided in each of the color channels for the insertion of neutral density filters. These filters provide for a coarse setting of each primary color value for color balancing purposes. The combined light passes through five condenser elements (four cylindrical and one spherical) whose purpose is to concentrate the light beam at the printing aperture to assure optimum illumination. A solenoid-actuated douser is provided to cut off the light from the film when the printer is stopped. An additional filter holder is immediately behind the douser for filtering the integrated light.

Light valves and trimmers. The three light valves are identical and interchangeable. Each valve contains the memory selector, the shutter actuating mechanism, and the shutters in one integral unit. The light valves and trimmers provide for color correction in 72 individual steps of 0.025 log E increments, for a total range of 1.80 log E. Fifty of these exposure valves are automatically controlled by tape signals from the reader memory selectors; the balance is established by manually turning the trimmer knobs to shift the entire scale of automatically controlled steps upward or downward. In this way, the same tape may always be used for the same original negative, and variations in color balance of print stock having various emulsion numbers may be compensated for by changing the trimmer setting.

With manual settings of 1 to 24, the trimmer knobs provide a light value range of 23 actual steps (0.575 log E total), while the automatic tape program provides a range of 49 actual steps (1.225 log E total). Thus, if a tape were programmed at light 1 throughout, the light value could be varied form 0.00 to 0.575 log E by changing the trimmer setting from 1 to 24. The trimmer settings also control the light value range available for automatic programming. For example, with a trimmer setting of 1, it is possible to program a tape with light values of 1 to 50 for a total of 1.225 log E; with a trimmer setting of 24, it is possible to program a tape with light values of 24 to 73 (also for a total of 1.225 log E). It is obvious, however, that each of these trimmer settings will permit a light correction (for variations in color balance and emulsion numbers) in one direction only. At a trimmer setting of 1, light values can be increased only (from 51 to 73); with a trimmer setting of 24, light values can be decreased only (from 23 to 1). In general practice, trimmers are set at 12, thus permitting an 11-step decrease and a 12-step increase in programmed light values.

Program tape reader. To this point in your CDC, there has been no discussion of program tapes as they apply to motion picture printing. Chapter 4 of this volume discusses this subject in detail. However, since the 6100C printer contains a program tape reader, it is only fair to discuss this reader while discussing the other aspects of the printer. All you have to know at this time is that tapes are used to program such printer functions as exposure changes, special effects, etc. The tape reader on the 6100C printer is of the intermittently operating pin-sensing type where operation is under the control of a camshaft which makes a single revolution to read each row of code. The reader advances four rows per each cue signal—one step for the blank space between information, and three to read out the red, green and blue information sequentially. In black-and-white printing, all channels of light are uniform. Such a program is obtained by pressing the BW button on the tape punch. The reading pins move under light spring tension into engagement with the tape while the tape is stationary. If there is a code hole in register with a pin, the pin moves through the tape to a position which allows an associated contact assembly to operate. If there is no code hole at this point, movement of the reading pin is blocked by the tape and the contact assembly remains inactive.

The reader is provided with a tape contact (no tape) switch so that the clutch cannot be actuated with the AUTO start button unless a program tape is in place. Also, the TEST start button is inoperative when a program tape is used.

The tape reader is the heart of the automatic operation of the printer. By reading the perforated tape, it creates properly timed signals to select the intensity of the three color light beams; it selects the right fade length, and it starts and stops the printer. In addition, the reader contains the means to verify its own functions for proper sequence and to stop the printer immediately in case of a malfunction of some component which would cause the print to be unusable.

NOTE: On all printers, the manual CUE and FADE buttons are operable during automatic operation. Do not depress them accidentally.

The following is a condensed, step-by-step outline of the automatic printer operation discussed in the preceding paragraph:

(1) On AUTO start, the tape advances to the first program which is read out and placed in memory as the printer drive is started.

(2) A cue is required to place any program into the shutters. An automatic first cue on AUTO actuates the first program into shutters. This is a selective feature and may be eliminated in favor of a notch in the first scene.

(3) As the cue for utilizing the first program is signaled, immediately afterward the readout for the second program occurs and is placed in memory. Each succeeding cue then causes a similar action.

(4) As the cue for the last program is signaled and this program is utilized, the leader advances the tape to present a "no-hole" situation, which places the zero-close in memory.

(5) A cue now is required, past the end of the last scene, to cause the reader to advance the tape to the "end" hole, thereby stopping the printer. On this cue the zero-close program in memory is actuated into the shutters.

Exercises (518):

1. Explain what correction should be made within the optical system of the 6100C printer when it is producing too much red in the exposing illumination.

2. When the last scene has been printed on the *6100C* printer, the printer transport system does not stop. What could cause this failure of the transport system to stop?

3. The printed product analysis indicates that the duplicating material was subjected to too much infrared radiation during exposure. What could cause this?

4. While printing several copies of a motion picture scene, the supply of duplicating stock is depleted. A new duplicating stock is used to finish the project, but there is a noticeable change in the color balance. What did the operator probably forget to do?

519. Given 6100C printer malfunction that can be associated with operating controls, state the cause of each malfunction.

Operating Controls. Most of the printer controls are located on the pushbutton panel, the instrument panel, and the rear control panel. These panels are shown in figure 8-10. The number in parentheses after the control represents the item in figure 8-10.

a. The AUTO button (20) is used to start the printer in the automatic mode of operation. This button is inoperative when no tape is present in the reader or when tape is present but the fader is closed. It also should be noted that the AUTO button will not start the printer if the roller gate is open. The AUTO button is held depressed until the first tape program reaches the reading pins of the reader, then it may be released.

b. The TEST button (22) is used to start the printer for checking purposes. This button is used when no tape is present in the reader; therefore, no light changes can be accomplished after a "test" start. The TEST button starting operation is not affected by an open roller gate, a closed fader, or the negative film break switch.

c. The STOP button (21) is used to stop a printer that has been started with the TEST button or the alternate start-stop button on the tape reader. It also may be used to stop a printer in automatic operation, although this is normally done by the "end" hole in the tape.

d. The MOTOR circuit breaker (4) is used to switch AC voltage to the drive motor and the takeup motors.

e. The POWER circuit breaker (5) is used to switch AC voltage to the reader and to the DC power supply.

f. The LAMP switch (7) switches AC to the lamp and rheostat blowers and DC to the printing. This switch MUST BE OFF when the DC switch is on.

g. The HI-LO switch (11) shifts printing voltage from high range to low range and is used in conjunction with the "fine" and "course" lamp rheostats.

h. The LAMP FINE rheostat (8) is used together with the HI-LO switch and lamp coarse rheostat to adjust printing lamp illumination level.

i. The VOLTMETER rheostat (16) is used to adjust the level or voltmeter dial illumination.

j. The FADER indicators (2,3) provide an immediate visual indication of the position of the FADER (OPEN or CLOSED).

k. The SPEED indicators (13, 14) provide an immediate visual indication of the printer speed (60 or 180 feet per minute).

l. The EDGE PRINTER rheostat (26) controls the brilliance of the edge printer lamps.

m. The EDGE PRINTER switch (26) controls the edge printer lamps. If this switch is in the ON position during automatic operation, the edge printer lamps automatically turn on and off as the printer starts and stops.

n. The AC switch (28) is the master AC switch and when in the ON position, it switches all AC power to the printer. The two utility outlets (36) on the control panel have AC present whenever the printer is connected to an AC source.

o. The LAMP COARSE rheostat knob, located on top of the vane housing, is used together with the HI-LO switch (11) and the LAMP FINE rheostat (8) to adjust printing lamp illumination level.

p. The DC switch (27) switches the external supply to the printer for the printing lamp. IMPORTANT: Do not switch on the DC switch unless the LAMP switch (7) is off.

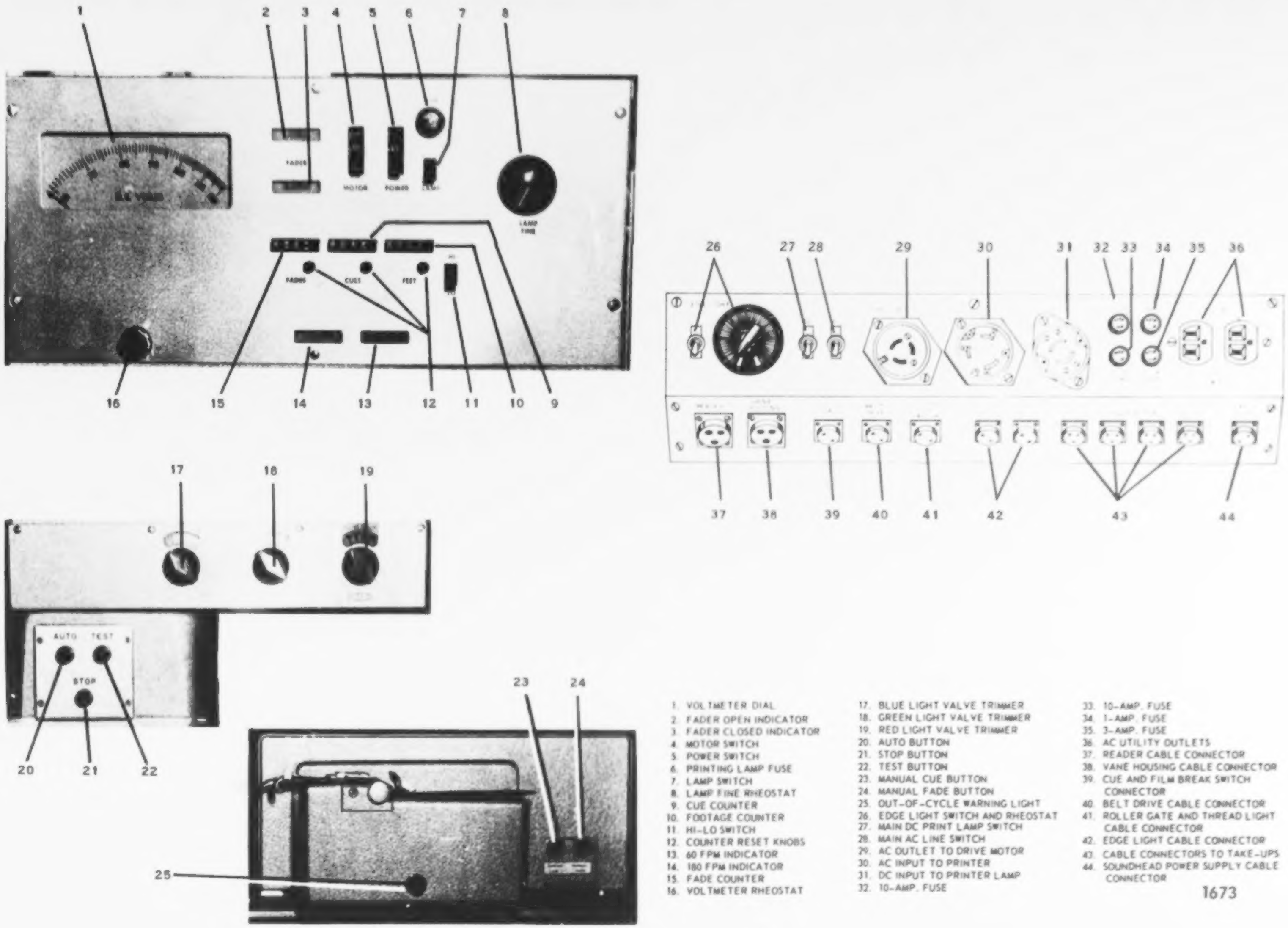
q. The three LIGHT VALVE trim knobs (17, 18, and 19, one for each color) can be rotated in either direction and are detented at each light number from 1 to 24. Each value, from one detent to the next, is identical with the steps on the program tape for manual color balancing.

r. The OPERATING SPEED change control is used for changing printer operating speed and is located on the belt drive assembly.

s. The ALTERNATE START-STOP button is located below the front right-hand corner of the reader and can be used to start and stop the printer with or without tape in use. Its principal function is to douse the "out-of-cycle" warning light when the occasion demands.

t. The MANUAL CUE button (23), if depressed, causes a "cue" to be signaled to the printer in the same manner as the cue notch or cue patch triggers. The printer must be ON, with the notch cue switch OPEN (film threades so that the cue actuating roller rides the edge of the film) before the MANUAL CUE button will operate. Since this button can operate while the printer is in automatic operation with film threaded, the operator must be careful not to press the button accidentally.

u. The MANUAL FADE button (24), if depressed, causes a 16-frame fade to be placed in memory. The


1
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FADER
MOTOR
POWER
LAMP
LAMP FINE
FADES
CUES
FEET
HI
LO
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AUTO
TEST
STOP
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24
25

1. VOLTMETER DIAL
2. FADER OPEN INDICATOR
3. FADER CLOSED INDICATOR
4. MOTOR SWITCH
5. POWER SWITCH
6. PRINTING LAMP FUSE
7. LAMP SWITCH
8. LAMP FINE RHEOSTAT
9. CUE COUNTER
10. FOOTAGE COUNTER
11. HI-LO SWITCH
12. COUNTER RESET KNOBS
13. 60 FPM INDICATOR
14. 180 FPM INDICATOR
15. FADE COUNTER
16. VOLTMETER RHEOSTAT
17. BLUE LIGHT VALVE TRIMMER
18. GREEN LIGHT VALVE TRIMMER
19. RED LIGHT VALVE TRIMMER
20. AUTO BUTTON
21. STOP BUTTON
22. TEST BUTTON
23. MANUAL CUE BUTTON
24. MANUAL FADE BUTTON
25. OUT-OF-CYCLE WARNING LIGHT
26. EDGE LIGHT SWITCH AND RHEOSTAT
27. MAIN DC PRINT LAMP SWITCH
28. MAIN AC LINE SWITCH
29. AC OUTLET TO DRIVE MOTOR
30. AC INPUT TO PRINTER
31. DC INPUT TO PRINTER LAMP
32. 10-AMP. FUSE
33. 10-AMP. FUSE
34. 1-AMP. FUSE
35. 3-AMP. FUSE
36. AC UTILITY OUTLETS
37. READER CABLE CONNECTOR
38. VANE HOUSING CABLE CONNECTOR
39. CUE AND FILM BREAK SWITCH CONNECTOR
40. BELT DRIVE CABLE CONNECTOR
41. ROLLER GATE AND THREAD LIGHT CABLE CONNECTOR
42. EDGE LIGHT CABLE CONNECTOR
43. CABLE CONNECTORS TO TAKE-UPS
44. SOUNDHEAD POWER SUPPLY CABLE CONNECTOR

1673

Figure 8-10. Model 6100C controls.

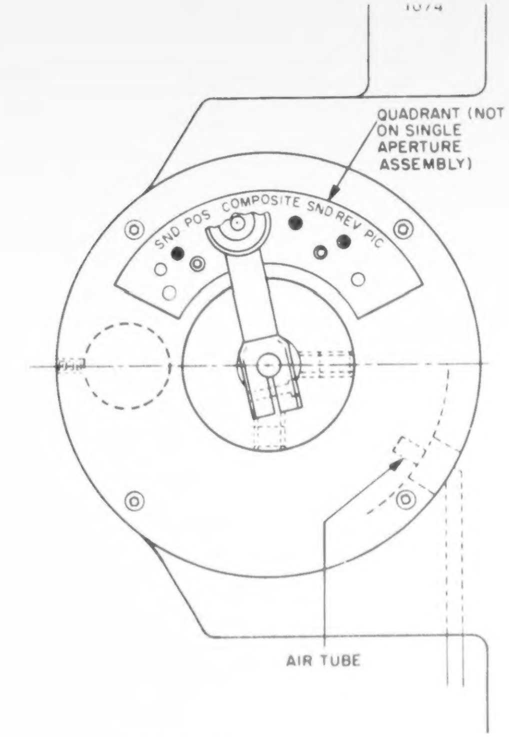


Figure 8-11. Four-way aperture jaw.

manual fade button also functions during automatic operation, and precautions must be taken to avoid accidental triggering of the fade signal.

v. The CUTOFF switch for the takeup motors cuts the power to the motors when the tight-wind guide roller is raised to its upper position. The roller latches in place and can be released by pressing a button on the tight-wind frame or on the guide arm.

w. A PRINTING APERTURE SELECTOR of the rotating drum type is included on the 16-mm, 35-mm, and 35/32-mm printers. One 16-mm model and all 70-mm models have a single aperture. Selective apertures are positioned by rotating the selector lever, shown in figure 8-11, and detenting it in the proper hole. Spring tension holds the lever in the detent position.

NOTE: A green light of low intensity is reflected through the aperture when the gate is opened. This light is used to facilitate synchronization at the aperture.

The printer incorporates many safety features to insure accurate and trouble-free printing results.

The printer drive motor starts in a gradual acceleration, gaining full operating speed of 60 fpm or 180 fpm, whichever has been selected by the operator. This gradual acceleration feature protects the film against accidental breakage which might otherwise be caused by sudden starts.

The takeup motors are provided with a low-torque takeup action during automatic starts. This feature remains in effect while the AUTO start button is being depressed.

If the film negative should part during operation, the CUTOFF switch stops the printer and takeups and closes the douser. The switch is actuated by the spring-loaded film motion stabilizer and has a short time-delay on opening the circuit so that short, quickly recovered movements of the stabilizer do not cause the printer to stop.

The tape reader contains a checking circuitry to detect any out-of-cycle condition that might signal a program to the wrong light valve. The warning system detects an "error" if the tape is inadvertently moved (manually) or set at an erroneous position relative to the first row of holes in the tape and the readout pins of the reader. Upon detection, the printer stops automatically and the red indicator on the reader lights to signal that an out-of-cycle condition exists.

The opening of the roller gate actuates a switch that cuts off the power to the drive motor, the takeup motors, and the douser mechanism. This cutoff is effective only when the printer is operating an AUTO start.

When the fader is in the CLOSED position (CLOSED indicator on instrument panel lit), a cutoff to the circuit of the AUTO button is put into effect, and the printer is prevented from starting on AUTO start. This feature may have been reversed on your particular printer (that is, AUTO start prevented when the fader is in the OPEN position). In either case, the printer cannot be started until the position of the fader is reversed manually. Test-start circuitry is not affected by this CUTOFF switch.

Exercises (519):

1. The 6100C Printer is threaded with material and tape. The AUTO button is depressed but the printer does not operate. What could cause this malfunction?

2. You are printing film that has been cued. However, the printer does not automatically cue. What could possibly cause this?

3. The 6100C printer is readied for operation and threaded with material. When the AUTO button is depressed to begin material transport, it is found that the button is inoperative. What could cause this?

4. At the completion of an automatic printing run, the printer is stopped but the edge printer lamps do not go out. What task was not accomplished that resulted in these lights remaining on?

5. During operation, the printer stops operating and the red indicator on the reader lights. What would cause this condition?

520. Given hypothetical situations that can be associated with the 6100C printer startup, give the probable cause for each situation.

Operation. Figure 8-12 illustrates the proper threading of stock and negative for printer operation without the soundhead. Note the path of the film when using the RF cuer (item 7 in fig. 8-13). After film is threaded, be sure to close the film roller gate and lower the tight-wind rollers to the film.

In order to provide a single pass picture and soundtrack printing capability, a soundhead can be added to the 6100 printer (16-mm) or the 6200 printer (35-mm). Sound can be printed without the use of this soundhead if the printer is equipped with a 4-way (SND-POS)., head. However, if the printer was, for example, programmed for fades, the soundtrack would also be faded. With the added soundhead, the picture only (with fades) is printed as a function of the soundhead attachment.

Refer to figure 8-13 for a threading diagram when the soundhead is mounted on the printer. Film is transported past the sound aperture by a sprocket driven through a gear train from the picture head. A drum, integral with the sprocket, supports the negative across to the edge of the track aperture. The roller gate, adjusted to a slight pressure, rides the full width of the stock film to provide contact with the negative in front of the aperture.

A filter holder is provided for three quarter-inch square gelatin filters to modify the exposing light. These filters are cooled by an air supply to this area. In addition, this air supply cools the lamp, keeps the aperture clean, and aids in providing better contact of the printing materials. It is suggested that this air supply be filtered against injection of dirt and excess moisture.

The dual-aperture soundhead incorporates a single aperture adjustable to two sizes by the use of a sliding edge controlled with a two-way selector knob. When you are using either the single or four-way aperture picture heads (both of which have only one size picture aperture), move the selector head on the soundhead to REV for printing on reversal material and to POS when printing on negative or positive materials.

The soundhead incorporates its own DC power supply, which is equipped with a constant voltage transformer and a filter choke to provide ripple-free DC.

Before operating the printer, you must first thread an appropriate program tape in the reader. Flip the sprocket guard away from the sprocket (thus lowering the NO TAPE switch). Thread the tape sideways over the switch, under the reading pin cover casting, over the sprocket, and under the sprocket guard. Slip the tape into the slot at the bottom of the inside rail of the reading pin casting. Check to make certain that the transport perforations are engaged with the sprocket teeth, and close the sprocket guard. Slip the tape into the alignment guide at the left-hand side of the reader, and rotate the manual knob until there are approximately 3 inches of tape between the first program and the reading pins to be advanced. The reader is now ready for automatic operation.

When the printer is automatically stopped by the END program on the tape, the light valve shutters are actuated to the zeroclose position. On restarting, it is necessary to cause the shutters to open on some particular light value, which is the first program on the tape to be used. This can only be done by causing a cue pulse to occur after the first program is read out.

An automatic cue pulse is provided on current model printers for this purpose. This pulse occurs immediately after the printer starts on AUTO start and the first program has been placed in memory, and requires no cue notch (or cue patch) in the film. This automatic cue pulse occurs only at the start of each tape; all subsequent cue pulse must be signaled from a notch or patch on the film.

If the edge printer operation is desired, make certain that it is turned on. The 16-mm printer is equipped with a single edge number printer; the 35-mm, 35/32-mm, and 70-mm models with two. The printing apertures are directly in line with the picture aperture. The edge printer lamp is controlled by an ON-OFF switch on the control panel. When this switch is in the ON position, the printers turn on and off automatically as the printer starts and stops. Edge printer lamp brilliance is adjusted by means of a rheostat next to the ON-OFF switch to compensate for film type and printer speed.

Before starting the printer in automatic operation, the following steps and checks must be performed:

(1) Make certain that neutral density filters are in place when required. Filter frames are located in the vane housing directly ahead of each light valve and on the mount of the No. 4 and the No. 5 condensers. The former can be used to reduce the intensity of individual color beams in specific instances of color imbalance without resorting to resetting of trimmer knobs. The latter is used to reduce the intensity of the integrated beam when switching from fast (180 fpm) to slow (60 fpm) operating speed.

(2) Make certain that the optical compartment is tightly locked.

(3) Check to see that the printing lamp is turned on and the voltage is properly set. The proper lamp operating voltage is selected by the quality control section of the individual laboratory to correspond with the particular type of film being reproduced. Normally, this voltage is set for an operating speed of 180 fpm and the color beams balanced accordingly; then, when operating at 60 fpm, light beam intensity can be reduced by the insertion of a neutral density filter in the No. 4 and the No. 5 condenser filter frame.

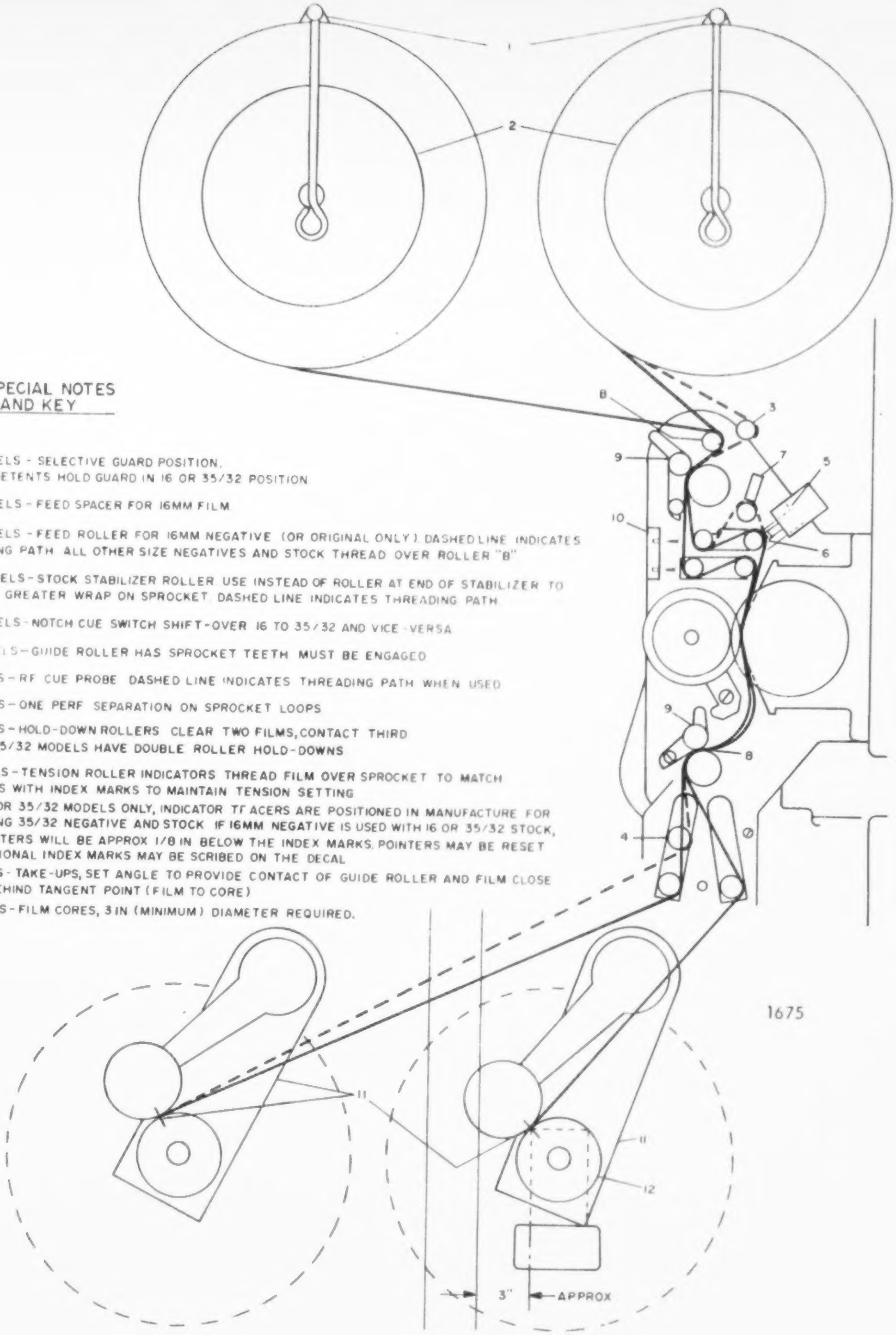
NOTE: If lamp voltage is altered by means of the lamp adjustment rheostats, color beams must be rebalanced in color printing.

(4) Be sure to select the desired printing aperture. On those printers having more than one aperture position, available apertures are clearly marked on the aperture nameplate. The single aperture 16-mm model has no track aperture incorporated into the picture head and requires the 16-mm soundhead attachment for soundtrack printing. This soundhead has a selective two-way aperture.

(5) Set the drive system for the desired speed and check to see that the proper speed indicator is lit.

(6) Reset all counters to zero.

(7) Check fade indicators. One or the other must be lit.



SPECIAL NOTES
AND KEY

1. 35/32 MODELS - SELECTIVE GUARD POSITION. SPRING DETENTS HOLD GUARD IN 16 OR 35/32 POSITION
2. 35/32 MODELS - FEED SPACER FOR 16MM FILM
3. 35/32 MODELS - FEED ROLLER FOR 16MM NEGATIVE (OR ORIGINAL ONLY) DASHED LINE INDICATES THREADING PATH ALL OTHER SIZE NEGATIVES AND STOCK THREAD OVER ROLLER "B"
4. 35/32 MODELS - STOCK STABILIZER ROLLER. USE INSTEAD OF ROLLER AT END OF STABILIZER TO PROVIDE GREATER WRAP ON SPROCKET. DASHED LINE INDICATES THREADING PATH
5. 35/32 MODELS - NOTCH CUE SWITCH SHIFT-OVER 16 TO 35/32 AND VICE-VERSA
6. 35/32 MODELS - GUIDE ROLLER HAS SPROCKET TEETH MUST BE ENGAGED
7. ALL MODELS - RF CUE PROBE DASHED LINE INDICATES THREADING PATH WHEN USED
8. ALL MODELS - ONE PERF SEPARATION ON SPROCKET LOOPS
9. ALL MODELS - HOLD-DOWN ROLLERS CLEAR TWO FILMS, CONTACT THIRD 16 AND 35/32 MODELS HAVE DOUBLE ROLLER HOLD-DOWNS
10. ALL MODELS - TENSION ROLLER INDICATORS THREAD FILM OVER SPROCKET TO MATCH POINTERS WITH INDEX MARKS TO MAINTAIN TENSION SETTING

    NOTE FOR 35/32 MODELS ONLY, INDICATOR TRACERS ARE POSITIONED IN MANUFACTURE FOR THREADING 35/32 NEGATIVE AND STOCK IF 16MM NEGATIVE IS USED WITH 16 OR 35/32 STOCK, THE POINTERS WILL BE APPROX 1/8 IN BELOW THE INDEX MARKS. POINTERS MAY BE RESET OR ADDITIONAL INDEX MARKS MAY BE SCRIBED ON THE DECAL
11. ALL MODELS - TAKE-UPS, SET ANGLE TO PROVIDE CONTACT OF GUIDE ROLLER AND FILM CLOSE TO OR BEHIND TANGENT POINT (FILM TO CORE)
12. ALL MODELS - FILM CORES, 3 IN (MINIMUM) DIAMETER REQUIRED.

Figure 8-12. Film threading diagram for Model 6100C printer.

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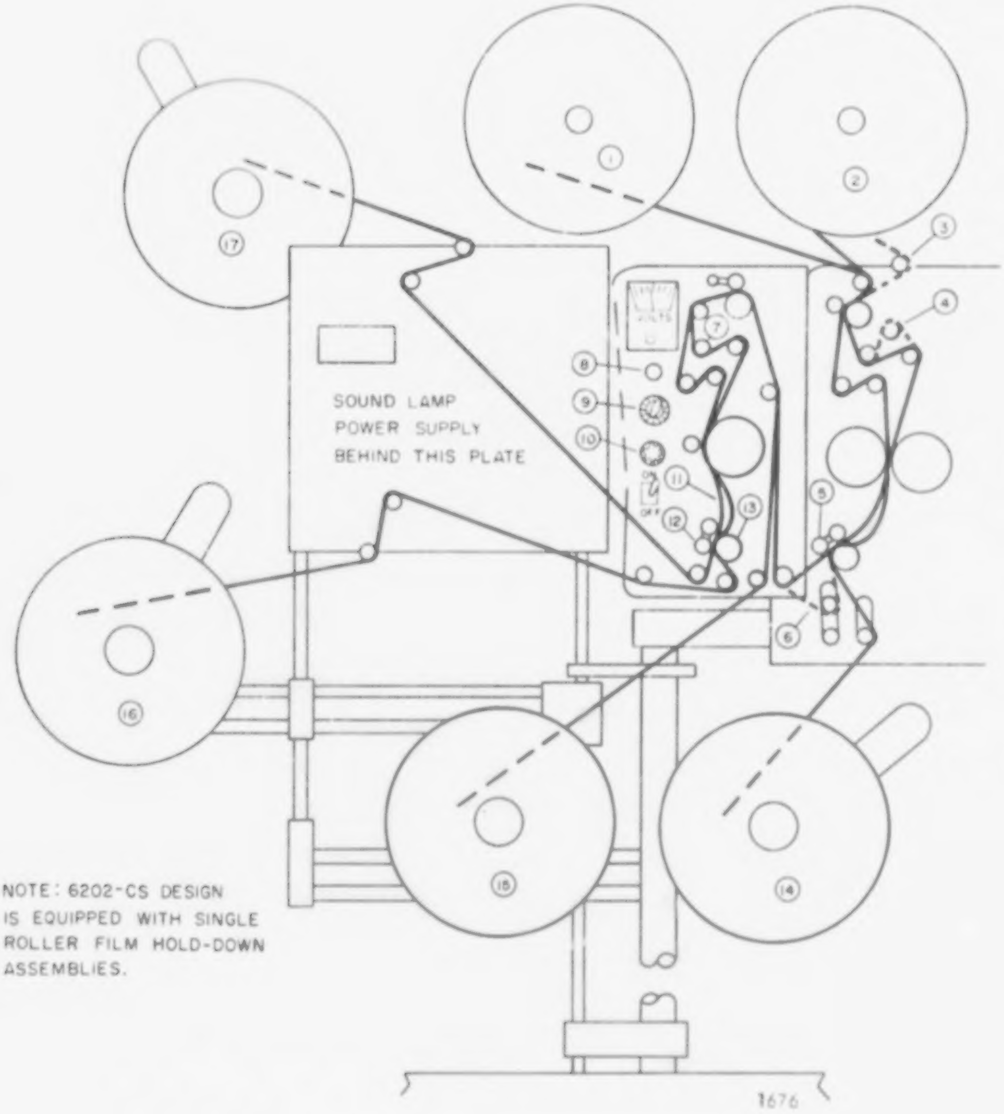
SOUND LAMP
POWER SUPPLY
BEHIND THIS PLATE
VOLTS
ON
OFF
①
②
③
④
⑤
⑥
⑦
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NOTE: 6202-CS DESIGN
IS EQUIPPED WITH SINGLE
ROLLER FILM HOLD-DOWN
ASSEMBLIES.

1 STOCK (PICTURE POSITIVE FEED)
2 PICTURE NEGATIVE FEED
3 PICTURE NEGATIVE
(FOR 16MM ON 35/32 MODELS ONLY)
4 R. F. CUER
5 ECCENTRIC STUD
6 STOCK ON 35/32 ONLY
7 TENSION ROLLERS
8 DIAL
9 COARSE } RHEOSTATS
10 FINE } RHEOSTATS
11 SEPARATE LOOPS BY ONE OR TWO
PERFS AT TAKEUP SPROCKET
12 ECCENTRIC STUD
13 TAKEUP SPROCKET
14 PICTURE NEGATIVE TAKEUP
15 SOUND NEGATIVE FEED
16 SOUND NEGATIVE TAKEUP
17 STOCK (PICTURE POSITIVE TAKEUP)

Figure 8-13. Soundhead threading diagram.

The fade indicator OPEN light must be on for automatic operations.

(8) If the printer is equipped with the RF cuer, make certain that the cue selector switch is in the desired position, RF or NOTCH–RF.

(9) Make certain that the program tape is properly threaded in the reader.

(10) Check to see that the trimmer knobs are set for the desired light values.

(11) Make a final inspection of film threading and check to make certain that the roller gate is closed and that the tight-wind rollers are lowered to the film.

(12) If edge printers are to be used, make certain that the edge printer switch is on and that the rheostat is properly adjusted.

Exercises (520):

1. The preceding printing run on the 6100C printer was made at a speed of 180 fpm. The operator has a requirement to print a roll of black-and-white film at 60 fpm. After processing, the duplicate is extremely dense. What did the operator probably forget to do to cause this high density?

2. During a printing run, the operator accidentally hits the lamp adjustment rheostats. What action should be taken before additional printing runs are made?

3. An unmodified 6100C printer is used to print a roll of motion picture originals containing soundtrack that is tape programmed for special effects and exposure changes. When the duplicate is projected, the sound fades in and out. What could cause this?

4. A roll of motion picture film is cleaned and then duplicated using the 6100C printer. When the duplicate is projected, there is evidence of dirt or dust being present during exposure. How can this be possible?

521. From a list of malfunctions during the operation of the 6100C printer, state the cause for each.

Printing Runs. Now that we have discussed the components of the printer and some of the operating procedures, let's look at how the printer is actually started, as well as some of the operating precautions.

The printer is started in the automatic mode by depressing the AUTO button on the pushbutton panel. The RESET START-STOP button on the reader will also start the printer for tape operation but will omit the low-torque (at start) takeup feature, and the tape will not advance until after the start and cue signal has occurred.

A number of operating precautions that must be followed are:

a. If the fade cycle is interrupted by a power failure or by the accidental cutoff of the main power switch or AC switch, the completion of the fade cycle must be accomplished manually.

b. If the MANUAL CUE button is accidentally depressed during automatic operation, a cue is signaled.

c. If the MANUAL FADE button is accidentally pressed during automatic operation, a 16-frame cue is placed "in memory" and will actuate on the next cue signal received.

d. If the STOP or the RESET START-STOP button is accidentally pressed during automatic operation, the printer will stop.

e. The takeups cannot operate unless the tightwind rollers are lowered down on the film.

f. The printer cannot operate if the negative break cutoff switch is actuated (improper negative threading may cause this condition).

g. If the tape is manually ratcheted erroneously during automatic operation, it must be returned to its proper location before the next cue; otherwise, the safety circuit will be tripped, stopping the printer. It should be noted, however, that the safety circuit will not the detect a condition wherein tape has been ratcheted exactly four steps (one complete cycle), or multiples thereof, out of position.

h. The Air inlet of exhaust vents on top of the vane housing must not be covered; otherwise, overheating will result.

i. The minimum scene length for light changes is 44 frames of 16-mm film (18 frames for 35-mm film) when operating at 180 fpm. These minimum scene length that will safely cue every program of a lengthy tape.

There must be a distinct interval of quiet (30 to 40 milliseconds) between the audible action of the next cue pulse while the pulse causes the vane solenoids to energize and move the vanes. Under no circumstances should there be an overlap of these audible occurrences.

The cue counter may be used to verify an overlap since the following cue will be missed. Always allow approximately 4 frames (16-mm), in addition to the fade length selected, after each fade and before the next cue notch. For example, for a 48-frame fade, allow 52 frames to the next cue notch. Where a fade length of less than 48 frames is programmed, the 44-frame minimum scene length must still be maintained at 180 fpm.

Since time is the important factor involved in this printer capability, it should be noted that operation at 60 fpm reduces all of the above limitations to one-third (both minimum scene lengths and length after fades). For example, at 60 fpm, the minimum scene length for light changes is 15 frames of 16-mm or 6 frames of 35-mm.

j. If the roller gate is open, the printer will not start on AUTO start and the douser will not open. TEST start is not affected by this feature.

k. If the fader is closed, the printer will not start on AUTO start (TEST start is not affected by this feature).

k. If the fader is closed, the printer will not start on AUTO start (TEST start is not affected by this feature).

l. On printers with RF cuers, the cue selector switch must be in the correct position; otherwise, cues cannot occur. The selector switch has two positions marked "RF" and "NOTCH-RF." With the switch on RF, a cue signal to the printer will be produced only from a cue patch. When using this setting, the film must be threaded over the SF nylon roller. With the selector switch on NOTCH-RF and the film threaded over the RF nylon roller, cue signals are produced both by patches and notches if both are present on the film. If notch cuing only is desired, use the NOTCH-RF switch position but do not thread film over the RF nylon roller.

Exercises (521):

1. During printing, a fade was not completed. What could cause this?

2. When viewing a recently exposed and processed scene, it is noticed that a fade occurs when it should not. What probably caused this?

3. The printer overheats during operation. What would cause this overheating?

4. During printer setup, the operator sets the cue selector switch to RF. After processing, it is found that the printer did not cue when it was supposed to. What probably caused this situation?

8-9. 6100C Printer Shutdown Procedures

As with the Niagara, the shutdown of this printer is not complicated. Let's now discuss these procedures briefly.

522. From a list of improperly conducted shutdown procedures, state the effect the procedures might have on subsequent operation.

The shutdown procedures for this printer are basically stopping the operation, allowing the lamphouse to cool, and good housekeeping.

The printer can be stopped at any time during operation by pressing the STOP button or the RESET START-STOP button on the reader. In normal operation, the printer is stopped by the end program in the tape.

A special restarting procedure must be followed when the printer stops during operation due to an out-of-cycle condition or to a blown fuse in the light value circuit. Refer to the manufacturer's handbook for this procedure.

During printing operations, a large amount of heat is built up by the exposing lamp. To combat the damage that might result if the heated air is not exhausted from the lamp house, the air circulation fan must be allowed to continue operation. If the lamp switch is turned off, both the lamp and fan become inoperative. However, turning off the DC power switch results in only the lamp being turned off.

Another important shutdown procedure is the housekeeping. Since this is more directly related to operator maintenance, it is discussed in that section. At this time, however, it should be emphasized that allowing the accumulation of any foreign matter can result in the production of pinholes in subsequent printing runs.

Exercises (522):

1. What might result if the following shutdown procedures are not properly accomplished?

   a. Cleaning the machine.

   b. Allowing the air circulation fan to continue operating.

523. With the aid of a troubleshooting chart, provide the probable cause of given malfunctions.

6100C Troubleshooting Procedures. The troubleshooting chart provides a means for checking the equipment troubles or malfunctions and references the probable causes and suggested remedies for each. The chart for this printer follows the same step-by-step sequence as outlined for other equipment previously discussed.

Table 8-2 is the operator's troubleshooting guide for the 6100C printer. While it is not the entire troubleshooting guide as listed in the TO for this printer, it is sufficient to point out many of the most common printer malfunctions. When using table 8-2 or the guide listed in the TO, you should remember that operating personnel must not try maintenance procedures that are beyond those authorized.

Exercises (523):

1. Using table 8-2, determine the probable cause for the following malfunctions:

   a. Notch cue does not operate.

   b. Takeup motor fails to operate when the TEST button is pressed.

   c. Fade counter does not register.

TABLE 8-2
OPERATORS TROUBLESHOOTING GUIDE (6100C PRINTER)

TROUBLE	PROBABLE CAUSE	REMEDY
Printer starts but accelera-tion is too slow.	Low AC input to printer	Check AC power polarity at receptacle. Refer to AC power requirements.
Douser fails to open.	Defective douser solenoid Open circuit.	Replace solenoid. Check douser circuit through the TEST and AUTO buttons. Repair or replace defective component.
Printer starts but one takeup motor fails to operate when TEST button is pressed.	Open circuit or defective motor.	Switch takeup motor cable connections on control panel as a check of trouble.
Face counter does not register.	Defective counter. Defective switch S501 in fader.	Replace face counter. Replace switch S501.
Printer does not start with alternate start-stop button.	Defective alternate start-stop switch. Open alternate start circuit.	Replace defective start-stop switch. Check continuity of alternate start circuit and repair or replace as necessary.
Notch cue does not operate.	Switch improperly adjusted. Defective notch cue switch. Open circuit to switch.	Adjust switch until notch in film loop positively acutates cue switch. Replace switch. Check continuity to switch circuit, locate and isolate defect. Repair or replace components as necessary.
Lamp and both blowers do not function.	Defective lamp switch. Open AC circuit.	Replace switch. Locate open circuit and repair as necessary.

524. State the purpose, basis, and limits of preventive maintenance of the 6100C printer.

Preventive Maintenance for the 6100C Printer. As has been stated so many times in this CDC, preventive maintenance is an important part of the life of the equipment as well as the quality of the material produced on the equipment. Now, let's look at the suggested preventive maintenance functions for the 6100C printer.

Purpose and scope of preventive maintenance. To keep the equipment at peak operating efficiency, it is vitally important that a regular and systematic routine of preventive maintenance be instituted and adhered to. Such a routine may be based on the number of hours of operation or the number of cues, or both. Actual printer running time is indicated on the hour meter mounted on the rear of the vane housing. Since most laboratories already have established routine maintenance procedures, it is suggested that you carefully examine your laboratory policy. In general, your responsibility in maintenance is limited to keeping the equipment clean.

Exercises (524):

1. Why is preventive maintenance important?

2. Systematic preventive maintenance for the 6100C printer should be based on what considerations?

3. As an operator, what is your responsibility in maintenance limited to?

525. Given a list of inaccurately performed maintenance functions, determine the probable effects on future printer operations.

Preventive maintenance functions. Pointed or sharp metal instruments must never be used to remove dirt or emulsion accumulation from any of the parts that come in contact with film. If ordinary cleaning methods do not suffice to remove accumulated dirt, use a spatula-shaped piece of wood (such as an orange stick or toothpick) to loosen the dirt. Then wipe the parts carefully with a soft, clean, lint-free cloth. It is also important that precautions be taken to guard against corrosion or physical damage to these parts.

Printer exterior may be cleaned with a cloth dampened with an approved nontoxic solvent of oil. The printer lamp voltmeter face is plastic and should not be cleaned with ordinary chemical cleaners. Wipe the roller, control sprocket, and other parts in the printing area with a soft, lint-free cloth. Inspect all sprocket teeth carefully and remove any accumulated dirt.

Clean printing apertures thoroughly with a soft camel's hair brush and/or an air hose. The air jet in the printing head may be used for this purpose, when there is no film in place over the aperture, by momentarily applying high air pressure. Condensers and cover glasses may be cleaned with soft, well-washed cotton cloths, such as diaper material. Commercial lens cleaning solutions may be used. Isopropyl alcohol may be used in the absence of other solutions. Clean the glass with a cloth dampened with the cleaning solution and immediately wipe dry with another cloth.

Dichroic mirrors should be cleaned only when absolutely necessary. Use only isopropyl or grain alcohol sparingly with soft cotton cloths or cotton swabs on the coated sides. The coated sides of the mirrors face the mounting frame. The back sides of the mirrors have no coating and need not be handled as cautiously as the coated sides. Do not use any solution containing distilled water on the mirrors. Dust should be removed from the mirrors and condensers, when it becomes present, by the use of a long bristled camel's hair brush which has been cleaned with ether. Dust should be dislodged from the glass with the brush and drawn away with a vacuum cleaner.

When cleaning the lamp blower, remove the four screws and lift out the blower air intake cover. Remove accumulated dust and dirt with a vacuum hose.

Whenever possible, components with exposed metal surfaces have been manufactured from corrosion-resistant materials. However, in some laboratories, the presence of chemical vapors and the cycling of temperature and humidity (particularly when the air conditioning is turned off) will promote corrosion. Obviously, installation and operation of the printer in a clean, constant-temperature atmosphere minimizes these undesirable effects. At the end of each day's operation, wipe (with a soft, lint-free cloth) the surface of the gate roller, printing sprocket, and convex surface on which the film rides.

The lubrication of the printer and its accessory items should be handled by qualified personnel, since considerable disassembly is often called for. Such lubrication is done on a schedule. A recommended schedule for lubrication is weekly, monthly, semiannually (1,000-hour), and annually (2,000-hour). Manufacturer's instructions should be carefully followed.

Exercises (525):

1. Explain the probable effects on printer operations or product quality if the following maintenance functions are inaccurately performed:

   a. Removing emulsion accumulation from metal rollers (as with a sharp instrument).

   b. Cleaning the printer lamp voltmeter face (as with ordinary chemical cleaners).

   c. Cleaning of dichroic mirrors.

CHAPTER 9

Motion Picture Printing Techniques

THE BASIC PRINCIPLES of printing motion picture film have been discussed in previous text segments. This is not, however, the full story. There are many specialized techniques to be considered and possibly accomplished before you reach the final product. Some of these techniques are required, while others are pegged to a particular system. Let's start with one of the required operations.

9-1. Special Effects

The production of special effects is often called synthetic photography. The effects are not real; they are artificial. Effects are produced in a number of ways, but the only ones we are concerned with here are the effects made by using a printer. These are called optical effects. The most common ones are fades (fade-in or fadeout), dissolves, wipes, and traveling mattes, which will be discussed separately.

526. Given descriptions of special effects, classify them as either fades, dissolves, or wipes and state the purpose of each effect.

Fades. A fade is said to occur when a scene gradually disappears into blackness (fade-out) on the screen or appears out of blackness (fade-in) on the screen. The effect is a type of transition between scenes. An effect of this type (as well as others) can be done in the camera but is most easily accomplished on a printer.

The effect is normally produced during the time when you are printing from a master positive to a duplicate negative. The master positive can be exactly reproduced as a dupe negative without modification between scenes. However, changes from one scene to another are abrupt. In a fade-out, the exposure on the dupe negative is gradually diminished to nothing as the end of a scene is approached. Each succeeding frame of the negative is exposed less and less; the image becomes weaker and weaker (after processing) until it eventually disappears. At this point, the negative is transparent. This negative is printed to a release positive, where the fade-out shows an image that gradually disappears as the screen slowly goes completely dark.

The fade-in of a new scene is just the opposite of the fade-out in all respects. The screen is completely black, and gradually the image appears. At first, the image is rather dark, but it gradually brightens until it is fully normal. A transition like this between scenes can be compared to the ending of one chapter in a book and the starting of another.

In general, fades are used for the following reasons:

- Begin and end of film.
- Separate titles from the first action.
- Separate chapters.
- Create dramatic breaks.

Dissolves. The dissolve is a variation of a combined fade-out and fade-in. Suppose you just produced a fade-out at the end of a scene. A definite number of positive and dupe negative frames went through the printer until the printer was stopped at the end of the fade-out. Now, suppose that the exposed film on which you just produced this fade- out is wound back so that it is in its original position at the point where the fade was started. Light is not admitted to the dupe negative during this rewind procedure. Also, the exposure controlling device is completely closed down at the start of this next procedure. The next scene on the master positive is ready for printing. In effect, we are going to make a double exposure on the dupe negative material. The printer is now started. At first, no exposing light reaches the dupe. Gradually, the new scene is faded in by an amount and film length identical to the fade-out. Thus, the total exposure on the dissolve length of film remains constant. One scene fades out in exact proportion to the fade-in of the other scene. The effect on the screen is a gradual disappearance of one scene while another scene gradually appears over it and eventually takes its place. The dissolve can last anywhere from 16 to 96 frames of film, but the Association of Cinema Laboratories, Inc. recommends 48 frames of film as the standard for dissolves. Dissolves are normally used in a production for the following reasons:

- Bridge a lapse of time.
- Provide a space transition.
- Separate a series of titles.
- Provide a change of pace from the usual, but abrupt, scene-to-scene cut.
- Provide a transition from live action to animation, and vice-versa.

Wipes. The name of this effect almost explains itself; the most common wipes occur when one scene seems to push another scene off the screen (fig. 9-1). This pushing can be from left to right, right to left, up, or down. Wipes can also be circular or even elaborate ones such as a star pattern or explosion. Many different kinds of wipes can be produced automatically in the more sophisticated printers. A printer of this type can cost upwards of $35,000.

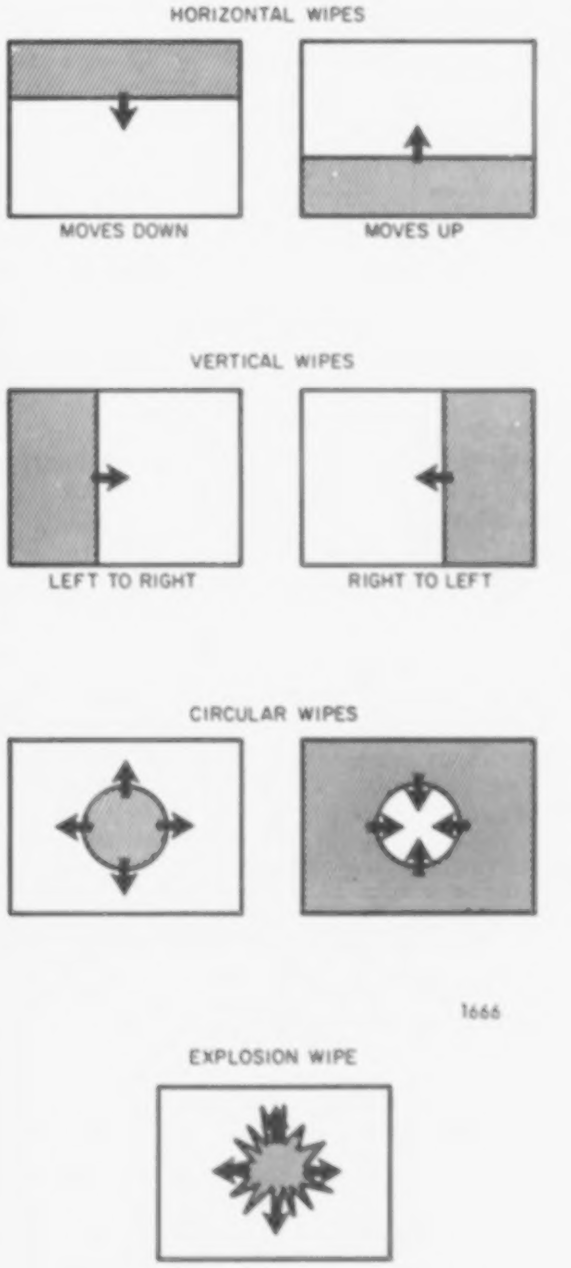


Figure 9-1. Typical wipes.

It is possible to produce wipes on almost any printer by using the traveling matte method. Mattes are lengths of film containing areas of black (opaque) and transparent film so arranged that a line of demarcation gradually shifts in successive frames. During a left to right wipe, for example, the first frame of the matte is transparent. As you progress from frame to frame, the black area slowly displaces the transparent area. Eventually, the entire frame is black and no exposure is made. As in a dissolve, the partially exposed film is now cranked back, and the other half of the exposure is made from a new scene. For the second exposure, the previously exposed film must be covered up by the black portion of the matte.

Some of the reasons for using left to right or right to left wipes are:

- Lead action in or out of the scene.
- Introduce a new or opposing thought.
- Separate related but confusing thoughts.

Some of the reasons for using an up or a down wipe are:

- Shorten a vertical pan.
- Create the feeling of a stage curtain.
- Give the feeling of ascending or descending.

Work Print Markings. When you are operating a printer, you may need to know the meaning of the various markings usually placed on a work print. Original negatives are rarely in the desired form for printing. A work print (positive) is made up to show the desired sequence of scenes, indicate the various special effects to be included, etc. This is a kind of rough draft of the final production. The work print is appropriately marked (with grease pencil) as shown in figure 9-2, which illustrates the more common markings. These markings may not be the same as the ones used in your organization. Then, the master positive is prepared (edited) in accordance with instructions on the work print. Using the master positive, it is your job to print the master positive to a dupe negative and include the various effects.

Exercises (526):

1. Classify the following effects as either fades, dissolves, or wipes:

   a. The effect in which one scene gradually disappears while the subsequent scene appears.

   b. The effect used when an animated figure pulls the next scene into a cartoon.

   c. The effect used when a scene gradually fades out into blackness.

   d. What is the primary purpose of fades, wipes, and dissolves?

   e. List the occasions when fades can be used in motion picture production.

f. List the occasions when dissolves can be used in motion picture production.

g. List the reasons for using wipes during motion picture production.

9-3. Motion Picture Timing—Manual and Automation

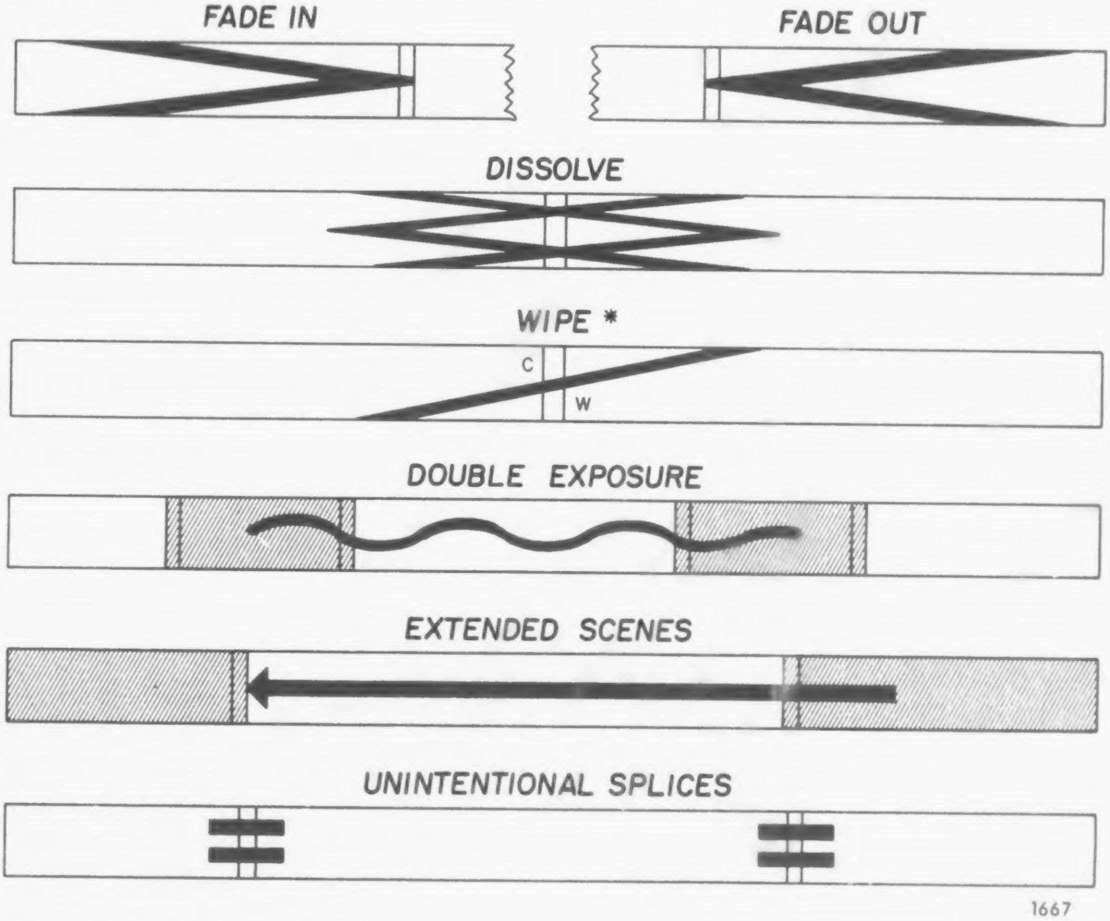
If an original negative (or positive) is perfectly exposed, your printing job is simple. Once the correct exposure is determined, all you have to do is print the roll. But a roll of negative can seldom be handled in this manner. Negative density varies from scene to scene and sequence to sequence. Therefore, one exposure cannot suffice. Also, some provisions must be made for introducing fades, wipes, dissolves and other special effects at the correct location during the printing step. These effects and exposure changes are programmed on a punch tape and the tape is then used to automatically control the printer.

527. Define motion picture timing and describe the two timing methods.

Timing. Timing, in the motion picture sense, is the act of determining the proper exposure for each scene. Each scene is individually examined by eye by viewing it over a light table or on a screen. The person doing this is called a timer.

To qualify for this job you must know the value, in terms of effective density, that one or more printer points will produce on the finished print. If your organization is equipped with many different printers, your job is much more complex.

Proper timing requires that you first determine what the principal subject is within a given scene. Since the subject must be reproduced as faithfully as possible, you direct your efforts toward this end in determining the proper exposure. There is a certain amount of artistic talent which



* CW INDICATES CIRCULAR WIPE

Figure 9–2. Work print markings.

you must possess in order to become a good timer. It is an undefinable quality that cannot be easily described. For instance, the desired mood which a producer hopes to impart can be enhanced or degraded, depending on the timer's talents in setting printing exposures.

Usually your timing operations are done by passing the film across a light table or other viewing device. Each scene is examined for possible exposure correction. The amount of correction is noted on a log. The printer follows such a log during printing and makes the necessary exposure corrections manually. Some printing machines are equipped to read notches cut into the film. Such notches trip a mechanism on the printing machine to signal the exposure change. Other printing machines use a punched tape along with film notching. Such a tape is prepunched on a tape program perforator in accordance with any desired automatic exposure changes.

It should be noted that timing procedures subject the film to a somewhat dirty environment. Therefore, after timing is completed, the film must be cleaned before it goes to the printer. In most cases, the film is sent to the printer heads out (the end of a motion picture film which is intended to be projected first) and ready for printing except for special cases where film is tails out. Obviously, film must be marked to indicate heads out or tails out.

Exercises (527):

1. What is meant by timing motion picture film?

2. In what two ways may motion picture original film be timed?

528. Determine the binary numbers for hypothetical programmed tapes.

Tape Programming. Several motion picture printers are capable of making automatic changes in timing from scene to scene. The printers are controlled by coded punched tapes. The paper tapes are all the same width and format, but they do vary in color and thickness. The tapes used with mechanical readers are light colored. Some printers employ a photoelectric reader and, as a consequence, use a black opaque tape. Generally, a black tape can be used in a mechanical reader if necessary, but the reverse is not true. Also, some perforators may not be able to handle the heavy black tape.

Printers, having a tape capability, incorporate a tape reader which interprets the timing information. This information is in the form of a binary code punched into the tape by a perforator designed to produce an exposure code for a specific reader and printer.

The binary code is one in which a particular signal, in this case the detection of a hole at a particular place across the paper tape, represents a numerical value. Several signals (holes) represent the sum of the individual values. A typical tape for use with the Models 6100 and 6200 printers is shown in figure 9-3. The tape shown in this figure illustrates how the punches can be used for programming color printing. The binary code uses five positions (holes). The values of these holes are 1, 2, 4, 8, 16, and 20 (see fig. 9-4). By taking a single value or some combination of the six values, it is possible to arrive at any number between 1 and 50. Also, additional punches on the other edge of the tape are used to signal fades, other special effects, start, and end. Information for the punching comes from the timer on a sheet showing timing information and scene description.

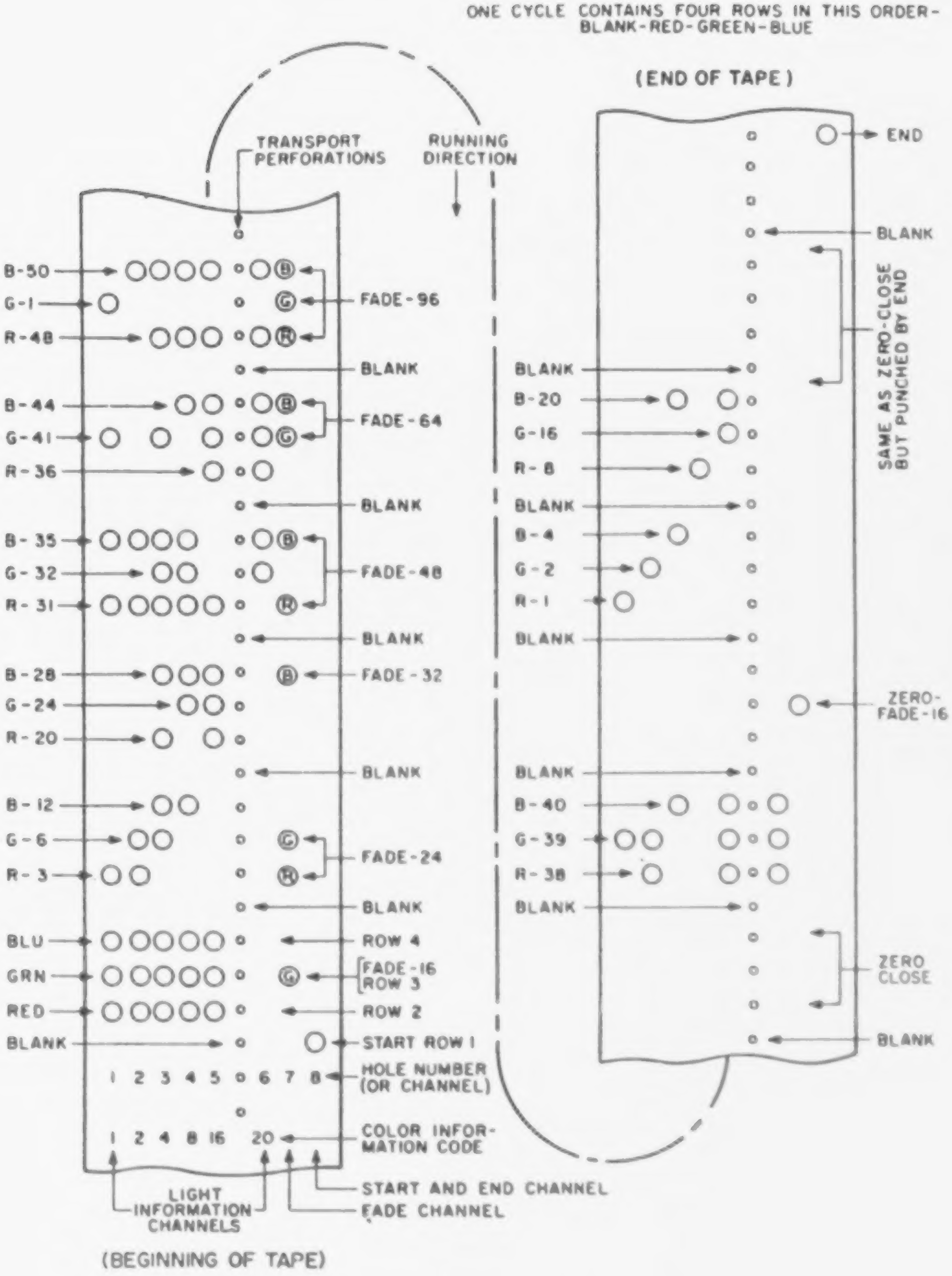

ONE CYCLE CONTAINS FOUR ROWS IN THIS ORDER-
BLANK-RED-GREEN-BLUE
(END OF TAPE)
END
BLANK
SAME AS ZERO-CLOSE BUT PUNCHED BY END
TRANSPORT PERFORATIONS
RUNNING DIRECTION
B-50
G-1
R-48
FADE-96
BLANK
B-44
G-41
R-36
FADE-64
BLANK
B-35
G-32
R-31
FADE-48
BLANK
B-28
G-24
R-20
FADE-32
BLANK
B-12
G-6
R-3
FADE-24
BLANK
BLU
GRN
RED
BLANK
ROW 4
FADE-16
ROW 3
ROW 2
START ROW 1
HOLE NUMBER (OR CHANNEL)
1 2 3 4 5 6 7 8
1 2 4 8 16 20
COLOR INFORMATION CODE
START AND END CHANNEL
FADE CHANNEL
LIGHT INFORMATION CHANNELS
(BEGINNING OF TAPE)
BLANK
B-20
G-16
R-8
BLANK
B-4
G-2
R-1
BLANK
ZERO-FADE-16
BLANK
B-40
G-39
R-38
BLANK
ZERO CLOSE
BLANK

Figure 9-3. Tape programming

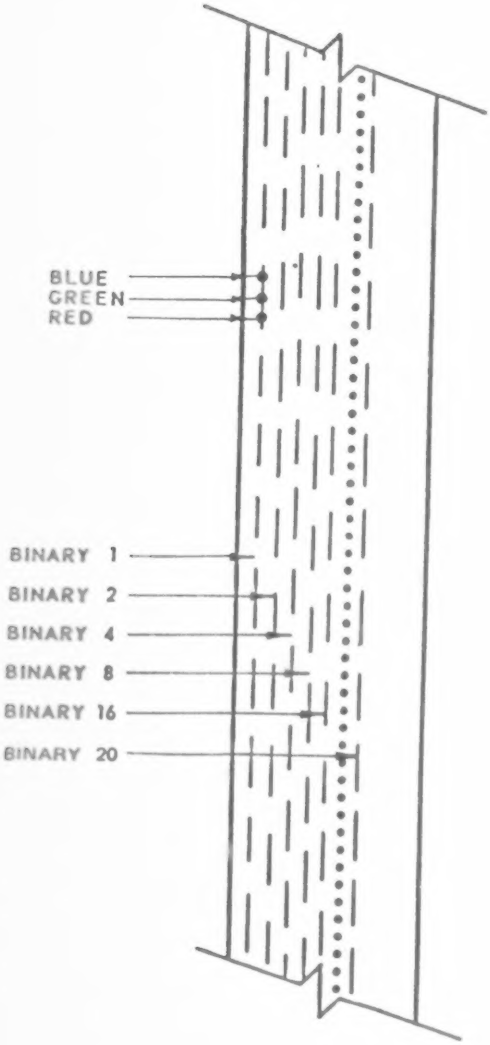
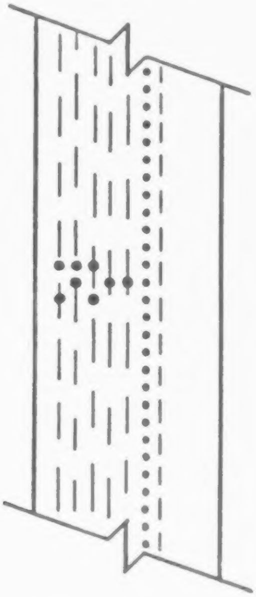

BLUE
GREEN
RED
BINARY 1
BINARY 2
BINARY 4
BINARY 8
BINARY 16
BINARY 20

Figure 9-4. Binary band identification.

Exercises (528):

Using figures 9-3 and 9-4 as references, determine the light value for each primary color for the programmed tape examples shown in figure 9-5. Consider the leading edge of the tape as being nearest the top of the figure.

1.

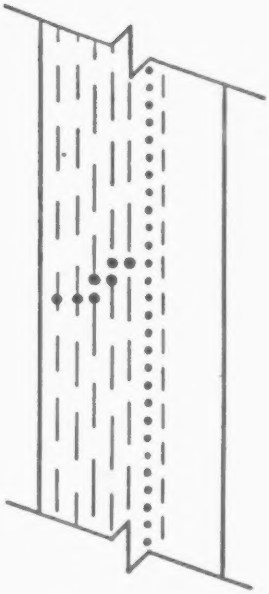


RED ______

GREEN ______

BLUE ______

2.

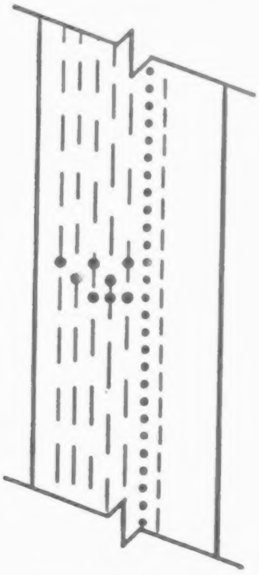


RED ______

GREEN ______

BLUE ______

4.

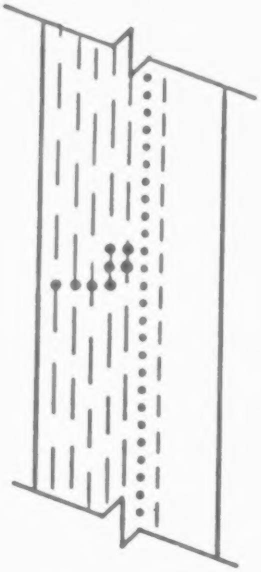


RED ______

GREEN ______

BLUE ______

3.



RED ______

GREEN ______

BLUE ______

Figure 9–5. Programming tape samples (objective 528, exercises 1–4).

1.

2.

3.

4.

9-3. Notch and Cue

Assume that the decision has been made as to which scene or scenes must have an exposure change, and you have decided how much. You must now provide a trigger to make such changes. The trigger can be a notch or the RF patch, depending on the type of equipment or your preference. Some printers use only notches, while others can use either or both.

529. Predict the probable results if certain tasks are not performed correctly during RF cuing.

Cuing System. On the 6100C printer, two cuing systems are available, either one of which causes emission of a signal pulse to the program tape reader. This signal pulse immediately energizes the light valve hutter solenoids and fader circuitry, causing them to respond to the light and fade information contained in the memory storage section. Simultaneously, this same pulse recycles the reader; thereby introducing the next series of light change and fade information into memory.

The most common cue system is *the notch type*, wherein the roller of the cue switch rides the edge of the film and is actuated by a notch cut in the film edge. *The RF cue system* utilizes either a single or double metallic patch and a proximity probe to generate a signal through a special amplifier, thereby eliminating the need for notching valuable original negatives. Both systems can be adjusted to obtain light changes and fader starts at precise locations with reference to the frame line. This adjustment is accurate only with the reader-printer combination for which it was initially adjusted. Any interchange of readers necessitates that a check be made on film, and probably requires readjustment of cue switch and probe positions.

One of the features of the 35/32 printer is a device to facilitate the shift of the notch switch from the 35/32 position to the 16-mm position without the necessity of vice is designed for the use of the 16-mm notch size to be used on both films.

The cue is automatically delayed to accommodate frame line synchronizing at both speeds of the 60- and 180-fpm system. As the speed selected switch is actuated, the delay is automatically changed. The cue switch must be adjusted for frame line sync at 180-fpm speed, and an electrical resistor in the reader is adjusted for sync at 60 fpm. Remember, the delay is accurate only with the reader-printer combination for which it was initially adjusted.

The notch cue system (standard equipment on every printer) is a device that provides a signal to the electrical system of the printer each time a notch in the negative film passes the cue switch.

The RF cuing system is a device that reliably causes a cue signal to be presented to the printer control system each time a metallic patch applied to the film passes under the probe. As the metallic patch passes through the magnetic field set up by the sensing coil of the probe, a relay in the amplifier is energized, thereby introducing a DC pulse to the printer cuing system.

The transistorized RF cuer consists of an amplifier, probe (sensing head), roller, and necessary mounting devices and electrical cabling to install the complete assembly on all C model printers.

A selector switch having two positions, RF and NOTCH–RF, is located on the control panel of the amplifier unit. This switch controls both RF and notch cue circuits of the printer whether or not the film is threaded over the RF nylon roller. With the switch on RF, a cue signal to the printer can be produced only from a patch. With the switch on NOTCH–RF, the cue signal is produced by both a patch and a notch if both are present on the film. Therefore, if the film has notches only, the switch must be set on NOTCH-RF. If the film has patches only, it makes no difference which setting is used. If the film has notches and has been retimed with patches and it is not desired to have the notches actuate the cuing system, the RF setting must be used. Any film having a patch that is to be used for cuing must, of course, be threaded over the RF nylon roller. If film has both notches and patches and it is desired to have only the notches actuate the cuing system, the switch must be set on NOTCH–RF, but the film must be threaded on the printer, bypassing the RF nylon roller.

The patch need only be 0.1 inch in diameter and 0.0015 inch in thickness and may pass under the probe with a spacing of up to 0.025 inch at a rate of up to 240 feet-per-minute. A single patch of this size is sufficient, but two may be used if desired.

The patch applicator is not included with the RF cuer. The patches are generally applied to the film with an applicator that punches and presses the patch onto the film in a single operation. The material used is aluminum foil with a pressure-sensitive adhesive backing, furnished in rolls. It is recommended that the patches be applied to the base side of the film, since the resistance to movement from the applied position is then greater when the film is immersed in cleaning solvents than when applied to the emulsion side.

Exercises (529):

1. Explain what might happen in the following situation:

    a. RF patches are applied to the emulsion side of the film, and it is then cleaned in an ultrasonic cleaner.

b. The patch which is to trigger a fade is less than 0.1 inch in diameter.

c. The selector switch of the 6100C printer is on RF. The film to be printed is cued with patches. The operator does not thread the film over the RF nylon roller.

530. Identify the cuing method that would activate printer changes for listed printing situations.

Cuing with Notches. The notch is a shallow depression cut into the edge of a film, usually with a hand punch. When the notch passes the reading device (a roller which actuates a switch), it causes the diaphragm or shutter to move to a predetermined position. The correct amount of printer light thus produces the desired change of exposure in accordance with the timing.

Notches are punched along the edge of the film during timing procedures. Be sure you position the notches in accordance with the desired positioning of the light changes. The exact position depends on the type of printer that is used. Remember, the sensing unit is not at the same place as the printing aperture. Therefore, the notch is offset along the film length to compensate. In other words, the cue is not alongside the frame where the light change takes place. As an example, the B and H edge-notching system requires that the notch be placed 4½ inches into the scene so that the density/color correction will occur exactly on the frame line of the scene being printed.

Normally, film to be notched is placed on the rewinds heads out, emulsion up, and travel is from left to right. The notch is placed on the film on the edge nearest the operator. The notch is appropriately positioned in accordance with the cue sensor of the printer.

While this method is normal for straight printing work, when notching A rolls and B rolls that require fade-in, fade-out, and lap dissolves, the method is somewhat different. In special effects printing work, the film may be notched to activate the fader only, activate the fader and the light change simultaneously, or activate the light change only. When the notch is placed on the film trailer, it is also used to stop the printer. In effects printing, notches may be placed almost anywhere in the roll of film, depending upon where an effect is required and the length of the effect.

In some cases of optical printing, it may be necessary to notch both sides of the original film to produce prints or masters in a desired emulsion position.

Exercises (530):

1. A film to be printed is cued with both notches and patches. If it is printed on the 6100C printer, which cuing method would trigger the programmed changes when the selector switch is in the following positions?

a. RF position with film threaded over RF nylon roller.

b. RF position with film not threaded over RF nylon roller.

c. NOTCH-RF position with film threaded over RF nylon roller.

d. NOTCH-RF position with film not threaded over RF nylon roller.

9-4. A- and B-Roll Cuing

In the previous section, we mentioned A and B rolls. Since the breakdown of motion picture films into A and B rolls is important to a motion picture editor, you should have a working knowledge of this process.

531. Cite the reasons for separating film into A and B rolls and explain how this task is accomplished.

Explanation of A and B Rolls. The original film, or dupe negative, is not usually spliced into a single roll. In many cases it is instead made up in an A roll and a B roll. One roll includes all the even-numbered scenes and the other includes the odd-numbered scenes. During printing, one run exposes every other scene to the raw stock. The second run exposes the missing scenes in between. Black leader splices into each roll between scenes permits this operation.

Cutting the original negative (or dupe negative) to match the completed work print is possibly the most critical step of editing, especially when cutting the camera original. Editing personnel are normally responsible for this function, but a knowledge in this area will make your job easier.

The primary items of equipment for this editing are a synchronizer, rewinds, a splicer, and a light table. The synchronizer and rewinds must be able to accommodate as many rolls of film as are to be able to be synchronized. A typical but complex job requires the synchronizing of six rolls. For example, the rolls to be synchronized are the work print, A roll B roll, A matte, B matte, and soundtrack.

A smaller but also typical 3-gang synchronizer and a soundtrack reader are illustrated in figure 9-6. The 3-gang unit is used to synchronize simpler productions; for example, a work print to a single picture roll and a soundtrack roll. Remember, the cutter is going to assemble the finished product so that it matches the work print, which is a coded set of instructions.

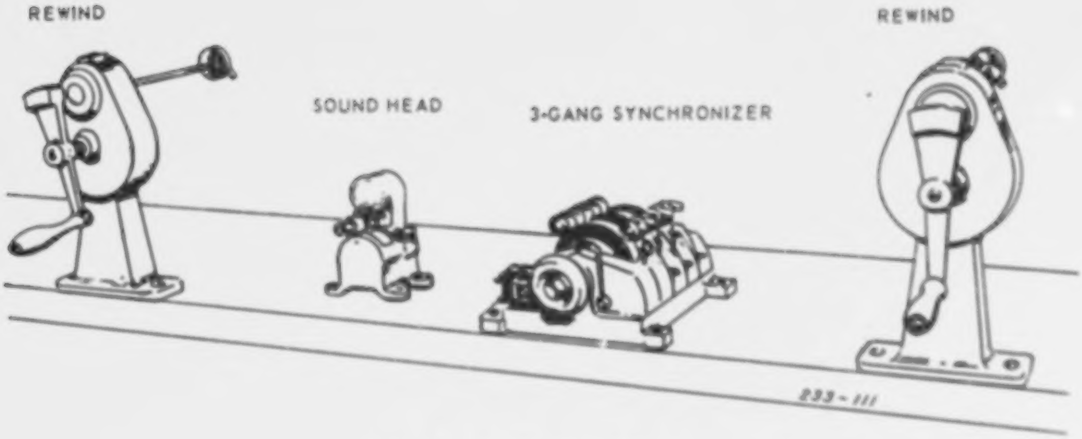


Figure 9-6. Typical splicing equipment.

When the negative cutter starts work, he or she first prepares a continuity list containing the starting and ending key numbers of each scene or the work print. When this is completed, he or she cuts up the negative into short lengths, usually scenes. These scenes can be hung up in bins or rolled up and identified by start and finish edge numbers.

Exercises (531):

1. Why is original motion picture film separated into A and B rolls?

2. How are A and B rolls synchronized to facilitate future printing runs?

532. Given situations that might occur during A- and B-roll cuing, explain the effect on the release print.

A- and B-Roll Makeup. The simplest job of editorial cutting is matching (conforming) a negative picture-only roll to a work print. This can be done on a 2-gang synchronizer. To facilitate the establishment of the cut points, a synchronizer includes a footage counter and a frame counter. The editor locks the work print into the synchronizer at the start point. This start point is located either at or very close to an edge number. If the start does not have an edge number, the work print is rolled forward until the number is in the synchronizer. The corresponding piece of negative is found and placed in the synchronizer so that its edge-number position matches that of the work print. Now, the editor checks detail to make sure that the match is perfect. Any excess of negative at the head end is cut off. Now, the head of the negative is fastened to a piece of leader. Both work print and negative are spooled up on their respective rewinds. When the end of the work print scene is reached in the synchronizer, the end of the negative is cut off and discarded. The work print is rolled forward until an edge number of the next scene is located. The corresponding scene of the negative is found, and the negative is locked in the synchronizer so that edge numbers match. The editor is now somewhere into scene two, so he backs up until he reaches the beginning of scene two of the work print. At this point, there might be an excess of negative at the head end. If so, he cuts off the excess and splices the negative scene two to negative scene one. He continues this procedure until the negative is completely matched to the work print and is ready for timing. The final stage before printing is to time and notch or RF patch the roll, as previously discussed.

An A-roll, B-roll technique is basically an expansion of the previous technique. Only in this case, two rolls are synchronized to the work print and also to each other. The A roll has all even scenes. Black leader is used in place of the odd scenes in the A roll. The B roll has odd scenes only, and black leader replaces the even scenes. This technique is used to facilitate the printing of special effects. All three rolls must be checked constantly during assembly to insure synchronization and identical matching to the work print. During this cutting, a cue card is prepared for the printer, indicating the special effects, their location, and the footage.

A part of this function of cutting also involves the soundtrack. A worktrack has been previously prepared to match the work print. The negative soundtrack must be matched to the worktrack. Tracks are also matched by edge number and/or by viewing specific sound modulations as represented by extreme density differences in a variable area track. All sound eliminated from the worktrack must be eliminated from the negative. After the negative track has been matched to the worktrack, the negatives are cut and spliced. It is also necessary that the final negative soundtrack be synchronized to the picture negative roll or rolls.

An editor will also place a sync mark on all rolls that are to be printed. This mark shows the start point for each roll. Thus, the printer is able to establish a start point for printing that requires more than one original negative roll and more than one pass through the printer.

Exercises (532):

1. During A- and B-roll assembly, the black leader spliced between scenes was not long enough. How would this affect the release print if not corrected?

2. What will happen if the work print soundtrack is not edited the same way that the work print is edited?

9-5. Specialized Printing Techniques

Quite often in motion picture and aerial reconnaissance, it is possible to remove the effects of minor surface scratches that are on the base of the original film. This is accomplished by using a specialized printing technique involving the use of wet gates during printing.

533. State the purpose of wet gates and how they operate.

Printing with Wet Gates. Wet gates are simply trays within the printer light path into which a liquid is placed. The frame being printed is immersed in this solution. As the scratches in the negative or positive are filled with the immersion liquid, they seemingly disappear. This is because the solution's refractive index is matched to that of the film base. The liquid wets, but is not absorbed by the film. Therefore, the film may be immediately rewound after the liquid is evaporated.

One of the liquids used in wet gates to remove the effects of base scratches, is a cleaning agent called tetrachlorethylene. This immersion liquid produces poisonous vapors which must be removed by an exhaust system preferably connected to an outside vent. The operator must wear a gas mask while operating the printer.

Exercises (533):

1. What is the purpose of wet gate printing?

2. How does the immersion fluid accomplish its objective?

3. Is the immersion fluid effective for both surfaces (emulsion) and base scratches? If not, which one is it effective with?

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Answers for Exercises

CHAPTER 1

Reference:

400 – 1. Checks are made for damaged film and rolls are assembled for processing.

401 – 1. (1) To keep from getting fingerprints on the film, and (2) so torn edges of the film will snag on the cloth fibers.
401 – 2. Such a tear always presents the possibility of film breakage during processing, even though tape is used along the edge of the film. Secondly, to cover such an area with tape could possibly hide important intelligence information.

402 – 1. b and d.

403 – 1. Too low a temperature during splicing.
403 – 2. The splice was too thick.
403 – 3. Improper angular relationship.

CHAPTER 2

404 – 1. The water pump will run dry and possibly burn out.
404 – 2. This would cause serious damage to the nylon gears and the drive.

405 – 1. 14½ fpm.
405 – 2. 20 fpm.
405 – 3. 7 fpm.
405 – 4. 17 fmp.
405 – 5. 22 fpm.

406 – 1. Temperature.
406 – 2. Flow rate.
406 – 3. Temperature and flow rate.

407 – 1. High.
407 – 2. No.

408 – 1. The negative was processed to too high a gamma.

409 – 1. Increased solution temperature.
409 – 2. Increased solution temperature.
409 – 3. Decreased solution temperature.
409 – 4. Decreased solution temperature.

410 – 1. Replenishment adds chemicals as they are used up, dilute chemicals that have built up, and adds fluid lost by carryover and evaporation.
410 – 2. a. Since restrainer is built up during the development process, the inclusion of potassium bromide in the replenisher would only enhance the restraining action, resulting in decreased densities and gamma.
  b. The most pronounced effect, if all other components are correct, would be a more energetic developer and subsequently higher densities and gamma.

411 – 1. Constant replenishment and control of bromide buildup through exhausted solution overflow.

412 – 1. 135 ml/minute.
412 – 2. 420 ml/minute
412 – 3. 125–130 ml/minute.
412 – 4. 180 ml/minute.
412 – 5. 410 ml/minute.
412 – 6. 380 ml/minute.
412 – 7. 225 ml/minute.

413 – 1. It depends on emulsion thickness, emulsion hardening, density of the image air temperature, relative humidity, and air movement.
413 – 2. Heated, high velocity air jets are simultaneously applied to the base and emulsion of the film; the temperature, relative humidity, and velocity of the air are adjusted [illegible] to prevent overdrying and underdrying. An efficient squeegee is necessary to remove excess water off the surface of the film before the film enters the drying cabinet.
413 – 3. a. Drying temperature is too high.
  b. Insufficient movement of heated air.
  c. Insufficient drying temperature or excessive dry-box humidity.

414 – 1. Yes—due to insufficient humidity.
414 – 2. Yes—due to excessive humidity.
414 – 3. Yes—due to excessive humidity due to insufficient air movement.

415 – 1. a. Contamination of the fixer by developer carryover.
  b. The film will not be completely fixed.

416 – 1. If the film lock does not operate properly, the end of the film will pass through the splicing assembly and into the machine. This will necessitate rethreading the machine.
416 – 2. These are indicators that the film lock has been activated. If they are not working, the entire accumulated film might be drawn into the solutions. When this happens, most processors automatically shut off.
416 – 3. The film cannot be cut cleanly.
416 – 4. If sufficient tape is not in the splicer, the splices cannot be made.

417 – 1. The edge of the film will probably snag and either stop the film movement or break the splice.
417 – 2. The sharp end might catch against a roller and tear the film.

418 – 1. No adjustments are necessary.
418 – 2. No adjustments are necessary.

419 – 1. To insure that the processor is not producing physical defects.

420 – 1. A roller with a circumference of 3 inches. Also, the film emulsion would have to come into contact with the roller (in the over-under threading system, a bottom roller).
420 – 2. Improper squeegeeing or blocked airflow.

421 – 1. No, they could not be caused by the processor. There is no roller this size that comes in contact with the emulsion.
421 – 2. Detector assembly (top rollers).

422 – 1. pH and specific gravity measurements and production of processed sensitometric strips.
422 – 2. (1) Drain the chemicals, (2) refill the machine with fresh chemicals, and (3) restart chemical certification.

423 – 1. The pH of the solution is increasing, which will result in higher gamma and densities.
423 – 2. Decreased overall densities, but most pronounced in the high density areas.
423 – 3. Increased densities in the low exposure areas (could be the result of increased base fog).

424 – 1. Prehardener, first developer, and color developer.
424 – 2. a. High blue and red points and low green points.
  b. Low blue and red points and high green points.
424 – 3. a. If the pH of the prehardener is too high the hardening action will increase and development will be retarded.
  b. If the pH of the prehardener is too low the hardening action will slow down causing overdevelopment.

425 – 1. Prehardener contaminated with fixer, first developer contaminated with prehardener, fixer, or color developer, color developer contaminated with first developer, prehardener, fixer, or bleach.
425 – 2. First and color developers switched; first developer contaminated with prehardener, fixer, or color developer; or, color developer contaminated with fixer.

426 – 1. Developing time, developer temperature, agitation, developer formula, material, and pH.
426 – 2. Solution temperature, solution replenishment, contamination, water flow rate, and pH.

427 – 1. The density range will be increased.
427 – 2. Color density will be increased.
427 – 3. The pH of the color developer will be increased resulting in high blue and low green densities.

428 – 1. Add replenisher until the pH of the developer is within standards.
428 – 2. The pH of the color developer is decreasing. Add the required amount of 7.0N sodium hydroxide.
428 – 3. Add 7.0N sulfuric acid to each liter of color developer.

CHAPTER 3

429 – 1. It speeds up the development cycle by providing maximum agitation while insuring that a constant fresh supply of solution is present.
429 – 2. Large quantities of solutions are necessary, and the processors are expensive.

430 – 1. Short rolls should be sorted according to size, emulsion-type, security classification, and assembled into large rolls for processing.
430 – 2. Consult, via intercom, with solution-control personnel to verify the solutions in the machines and the replenishment rate. Obtain results of a satisfactory scratch test from the inspection section.

431 – 1. Immersion-type systems are high capacity, economical, and adaptable to a wide range of film input rates.
431 – 2. It is somewhat slow.

432 – 1. Uneven development.
432 – 2. The film will probably not have sufficient and constant agitation. This could decrease density and gamma.

433 – 1. Excessive minimum density.
433 – 2. Too high a density range resulting in excessive maximum usable density.
433 – 3. a. Insufficient density to retain all required intelligence information.
b. Decreased density range.

434 – 1. The positive was processed to too high a gamma. Increased processing speed or decreased solution temperature would have resulted in less gamma.
434 – 2. The positive was processed to too low a gamma. Decreased processor speed or increased solution temperature would have resulted in higher gamma.
434 – 3. The positive was processed to too high a gamma. The high base fog only reemphasizes this point. Increased processor speed or decreased solution temperature would have resulted in less gamma and a lower base fog.

435 – 1. The dye which forms the antihalation backing is not being removed from the film until it reaches the first developer. The first wash which removes this backing is not being conducted.
435 – 2. A color negative would be formed. However, it would be of extremely poor quality.
435 – 3. The solution temperature is off. The thermometer should have been compared to a standard before using it to calibrate the processor temperature gauges.
435 – 4. Development mottle is caused by improper agitation. Since agitation is the product of material transport and solution recirculation, and the material transport is more or less constant for any given situation, the problem must be the result of recirculation. Some of the factors that should be checked to insure proper recirculation are pumps, clogged solution lines, and clogged solution filters.

436 – 1. Over-under.
436 – 2. Over-under.
436 – 3. Over-under.
436 – 4. Either the over-under or the loop.
436 – 5. Loop.
436 – 6. Loop.
436 – 7. Loop.

437 – 1. The amount of film in the accumulator tank and the transport speed.

438 – 1. 60 seconds.
438 – 2. 36 seconds.
438 – 3. Approximately 23 seconds.
438 – 4. Approximately 30 seconds.
438 – 5. 20 seconds.

439 – 1. Heading, subject, purpose, responsibility, abstract, references, procedure, and signature element.
439 – 2. (1) Narrow film, (leader-type threading), (2) wide film (leader-type threading), (3) wide film (leaderless type).
439 – 3. The staple method.
439 – 4. Cut the film at the accumulator tank, hand process what is in the machine, releader the machine, and continue processing.

440 – 1. Sight.
440 – 2. Hearing.
440 – 3. Sight.
440 – 4. Sight.

441 – 1. The first thing is to salvage the film. This might be accomplished by either increasing the dry-box temperature or air-drying the film. Once the film is salvaged, the next step is to notify Maintenance Control of the problem.
441 – 2. After the entire roll has been through the processor, reintroduce the film to the process at the fixing step. All subsequent steps must be completed.
441 – 3. With film narrower than 9½ inches, the adjustable rod-holders inside the magazine should be used with appropriate magazine rods.

442 – 1. Mistracking can cause crimped edges and tears. Another material transport defect can be the breaking of a splice due to film jamming in the processor.
442 – 2. Drying streaks and overdrying or underdrying.

443 – 1. Improper washing.
443 – 2. Stress on the film or mistracking.

CHAPTER 4

444 – 1. The transport is turned off as soon as all the material is out of the processor. This is to preclude having to use large quantities of leader.
444 – 2. The wash water is turned off after the transport. In this way, the leader that is in the drying compartment has been freed of processing solutions.
444 – 3. The drying compartment fan is the last to be turned off. This is because the hot air in the drying compartment must be circulated. As soon as the temperature reaches a level that will not cause damage to the heaters and material in the drying compartment, it too is turned off.

445 – 1. c, d, a, f, e, b.

446 – 1. a. Decreasing the machine speed was omitted. Because of this, when the processor is again started up, the transport system will attempt to begin operating at the same speed that it was operating when the machine was turned off. If the operating speed was high, then undue stress will be placed on the main drive motor and may result in damaging the transport system.
b. The dry-box thermostat was not turned off. Therefore, the drying compartment cannot cool off. The dry-box heating elements may overheat (when the blower is turned off, air is not circulated past the elements) and could result in fire, burned electrical connections, or blistering of material in dry-box.
c. OK.

d. Checking the replenishment valves was ignored. If not completely closed, this could result in replenishment continuing, rendering the solutions unacceptable for future use.
e. OK.
f. The main power switch was not turned off. The only effect this will have is that the main power to the system will automatically be turned on when the breaker switches are again turned on.

447 – 1. Sight (the elevator assembly rod would rise).
447 – 2. Hearing (the pump would squeek).
447 – 3. Sight (drying streaks would be evident).
447 – 4. Touch (the motor bearing would heat up).

448 – 1. Foreign particle in solution pump, or heat exchanger or recirculation system clogged.
448 – 2. Burned-out fuse.
448 – 3. Silver buildup on the rollers in developer racks.

449 – 1. The type of product needed, the speed at which the product is needed, and the product characteristics possible with each piece of equipment.
449 – 2. To keep the equipment operating as it should, producing a product that meets preestablished product requirements.
449 – 3. The color units are larger and more complex.

450 – 1.
- a. Burrs on crossover and turnaround shoes.
- b. Rack turnaround assemblies out of adjustment.
- c. Chemical buildup on rack rollers.
- d. Squeegee or crossover assembly twisted or not seated properly.
- e. Worn rack studs.

450 – 2.
- a. Roller binding in dryer entrance or exit crossover assemblies.
- b. Master roller on exit crossover not turning.
- c. Warped cluster rollers in exit crossover.
- d. Transport rollers dirty.
- e. Badly warped transport rollers.
- f. Dryer transport roller hesitating.
- g. Dryer temperature incorrect.

451 – 1. Chemical or foreign material buildup will eventually produce scratches or other abrasions in the film.
451 – 2. The developer might become contaminated with fixer.
451 – 3. Slack could buildup in the wet section and result in a wraparound.
451 – 4. If foreign matter is present in the air slits, uneven drying will result.

452 – 1. Probably, the old developer system filter cartridge was not removed and replaced with a new filter. If so, the filter would retain enough of the system cleaner to contaminate the new developer solution.
452 – 2. During cleaning, the splash guard probably was not in use. Therefore, when the fixer racks were taken from the processor for cleaning, the developer was contaminated with fixer.

453 – 1. Dichroic fog might be produced on the film being processed.
453 – 2.
- a. The pH might decrease, resulting in a decrease in process gamma.
- b. All the acid cleaner was not removed by the rinse water and was not neutralized by seasoning. Therefore, some remained in the system and decreased the alkalinity of the developer being used to process the film.

454 – 1.
- a. Kodak System Cleaner.
- b. Kodak System Cleaner or glacial acetic acid.
- c. Warm water.
- d. Glacial acetic acid.

454 – 2.
- a. Uncertified first developer.
- b. Uncertified color developer.
- c. Uncertified bleach.
- d. Uncertified prehardener.

455 – 1. When chemical cleaning solutions are used during processor cleaning.
455 – 2. Hot water.
455 – 3. By using a 1-percent solution of trisodium phosphate.

456 – 1. A rust-remover solution with a sodium hydroxide base may be used.
456 – 2. By immersing them in a chromic acid solution.
456 – 3. Since blasting is not allowed in the laboratory area, an aluminum cleaner or fiber brush will be used to clean these chemical tank tops.

457 – 1. Improperly applied corrosion techniques can cause more damage than if none at all were applied.
457 – 2. If the solution contained sodium hydroxide, the aluminum connections would soon deteriorate. Leaking of chemical solutions would soon begin.

CHAPTER 5

458 – 1. Conventional processors use either the immersion or spray systems, or a combination of both, for solution application. In the "Viscomat" system, a thin layer of the solutions, in a viscous state, is plated onto the emulsion layer.
458 – 2. Conventional and monobaths.

459 – 1. The normal (two-solution) processing.
459 – 2. Monobath processing system.

460 – 1. No. Eighteen minutes of solution at 18 feet-per-minute operating speed equal 324 feet maximum of film that can be processed.
460 – 2. The solution is not being pumped to the hoppers.
460 – 3.
- a. Depress the start switch and hold it for a few seconds.
- b. This takes up the slack in the leader and bypasses an electrical interlock.

460 – 4. Either the end-of-film detector roller in the supply chamber did not move downward or the magnetic brake is malfunctioning.
460 – 5. Improper alignment during splicing or a thick splice.

461 – 1. The image is formed on the final copy paper in the nontransfer system; the other system requires that the image be transferred before it becomes final.

462 – 1. On conventional printers.
462 – 2. Heat causes the used and unused developer to evaporate.
462 – 3. By a heat process or by using high-intensity light sources.

463 – 1. A processing technique by which the latent image is made visible by a means of a developer that contains a silver halide solvent.
463 – 2. As the negative image is being developed, the developer is also dissolving the unexposed silver halides. These are then transferred by a process of diffusion to the print material where they react with certain chemicals and form the positive image.

464 – 1. Exposure. Since a monobath solution is used in Polaroid products, it cannot be underdeveloped.
464 – 2. Overexposure. The more silver halides used during camera exposure, the less there are available to form density in the transfer (print) material.
464 – 3. A negative film, a high-viscosity developing solution, and a specially treated nonlight-sensitive positive transfer sheet.

CHAPTER 6

465 – 1. To break down the long processing rolls into smaller rolls.
465 – 2. These materials will contain mission identification information. This is necessary for laboratory personnel to identify any particular roll of film at any time.
465 – 3. By consolidating the accessories essential to roll film editing.

466 – 1. To separate roll into different sections according to density range.
466 – 2.
- a. Since cloud cover produced shadows that decreased overall density, these sections should be cut from the roll before printing. The material can then be spliced together for printing.
- b. The roll should be split into two sections. One will be of the sandy (high reflectance) terrain and the other of high foliage terrain (low reflectance). Each will require different printing criteria.

467 – 1. a, b, c, e, g, h.

467 – 2. To save manhours and materials and handling times for subsequent steps.

468 – 1. The method is preestablished for each unit and mission.

468 – 2. One frame from the ON may contain all of the information desired.

469 – 1. Film cement or heat splicing methods.

469 – 2. Tape splices.

469 – 3. They annotate the roll with identification information, and they provide leader and trailer material used for threading the continuous printer.

470 – 1.
- a. The film will mistrack during printing. Portions of some of each negative may be missed from the duplicate because of this mistracking
- b. Each negative will be numbered wrong; the last exposure on the roll will be numbered 1 instead of the first exposure being numbered 1. Furthermore, the photographic mission coverage trace will not plot correctly.

471 – 1. You should have checked items b, c, e, and f.

471 – 2. Project number, security classification, and footage or number of frames.

472 – 1.
- (1) d, e.
- (2) a, b, e.
- (3) a, b, e.

473 – 1. Facilitates the printing operation by reducing the time involved.

473 – 2. Savings in manhours; production time, and materials.

473 – 3. Exact records of the strip identification by mission must be maintained.

473 – 4. Split-printing and reassembled rolls according to density levels.

CHAPTER 7

474 – 1. Turn on main power switch, set No. 1 and No. 2 counter and type heater controls to maximum position for 10 minutes, then return heater control settings to counter heater 30 and type heater 48. Adjust incoming air pressure control regulators to set psig, and open counter sequencing air valves 1 and 2.

474 – 2. Ten minutes.

475 – 1. It determines the heating capability of the heating elements within the titler head. This, in turn, allows for correlation between the indicated and actual temperatures.

475 – 2.
- a. The transferred pigment will flow.
- b. The pigment will not transfer completely.

475 – 3. Too much pressure.

476 – 1. This is a form of flowing. The titling head heat should be decreased because it is too hot.

476 – 2. Temperature of the titling head should be increased.

476 – 3. The different thickness of film might result in insufficient pressure to insure proper transfer. No amount of head adjustment will correct this situation.

477 – 1. Operated by compressed air or other gas.

477 – 2. The titler head.

477 – 3. The speed at which the compressed air drives the head downward to imprint information on the film. The higher the air pressure, the faster the downward thrust, and subsequently the more pressure applied to the film.

478 – 1.
- a. Improper indexing results from a counter air pressure being too low. Increase the air pressure to this gauge.
- b. Embossing is caused by too much air pressure on the counter and/or type pads. Decrease air pressure on one or both of these pads.
- c. Illegible titles are caused by the pressure on the counter and/or type pads being too low. Increase the pressure on one or both pads.

479 – 1.
- a. In this situation, the even numbered frames are titled by the left head. Therefore, the counter and/or type pad gauges for this head are under too much pressure.
- b. The right head is not indexing properly. The air pressure on the right counter air pad should be increased.
- c. The right head produces the transfer information for odd numbered frames. In this case, both the counter and type pads probably are not under sufficient pressure. Increase the air pressure to these pads.

480 – 1. Damage to counter wheels will occur and will result in the titled information being broken (the lines forming any one character not being continuous) or illegible. Because of this, the counter will have to be replaced.

480 – 2. Two frames will contain the same number.

481 – 1. The titled characters will superimpose on the tape, resulting in illegible transfer.

481 – 2. If used to title film, flowing of pigment will occur.

482 – 1. From right to left, top to bottom.

482 – 2. 999.

483 – 1. The characters that are high will print. The characters that are low will not print.

483 – 2. The characters are made of lead and are soft. When the end screw is extremely tight, the characters nearest the screw are likely to bend. When this happens, the characters will strike the titling tape at an angle, imprinting only one side of the character.

483 – 3. It will take an extended period of time for the counter and type to reach operating temperature.

483 – 4. The increasing space between the information and the frame numbers indicates that the type holder is moving the head. The type block was not fastened in place with the retaining screw.

484 – 1. This procedure is wrong. The scrap film used for testing should be the same material as that being titled.

484 – 2.
- a. Wrong. The toggle switch should be turned to L to create drag on the supply spindle.
- b. Wrong. The toggle switch should be turned to R to create sufficient torque for film transfer to takeup spindle.

485 – 1. The titling tape is probably not advancing sufficiently and the characters are being superimposed over already used tape.

485 – 2. The printing cycle repeated before the film was advanced.

485 – 3. Both heads were used and the indexing was set wrong.

486 – 1. It is attached using an appropriate adapter, to the feed end of the processor.

486 – 2. A battery backup will be activated.

486 – 3. It is a very economical and fast way of providing a titled image.

486 – 4. The LED array exposes alphanumeric characters in a single line along one edge of the film, then the title is developed into a photographic image during the processing operation.

487 – 1. To remove dust and lint from aerial rollfilm.

487 – 2. From 70 mm to 9½ inches in width and up to 1,000 feet in length.

487 – 3. The cleaner contains a static eliminator unit which removes the static charges from the film.

488 – 1.
- a. The emulsion might be pulled from the base by the stress placed on the film.
- b. If not removed, the imbedded particles might produce pinholes (clear areas) or abrasions in the film.
- c. The cotton cloth produces lint which will adhere to the rollers. This decreases the cleaning efficiency of the rollers.
- d. Being in contact with the table top for several hours will cause a flat spot to form and, subsequently, will decrease cleaning efficiency.

489 – 1. d, f, h, a, c, e, g, b.

490 – 1.
- a. The film spool is not properly seated on the takeup spindle. The spool drive is turning, but cannot turn the film spool.
- b. Either the film supply bracket was not pushed completely forward and locked in position with the bracket knob, or the knob was not tightened and the bracket moved outward during operation.

c. The sensing arm was not positioned against the film takeup spool.

491 – 1. The transport speed of the cleaner should be decreased.

491 – 2. Show the new person the procedure for determining the fastest possible operating speed which will clean the film thoroughly.

492 – 1. The transport mechanism could be set at some high speed. If this is the case, when the transport speed is switched on, the unit tries to go from zero to some high speed instantly. This could possibly result in the transport motor burning out.

492 – 2. A high static charge is built up on the film. If this charge is not eliminated, it will attract more dust and dirt to the film.

492 – 3. The entire unit will become contaminated. However, the most pronounced effect of this contamination is with the tacky rollers. Dust and dirt might become imbedded in these and, subsequently, will damage the film that is cleaned on this cleaner.

493 – 1. Cavitation is the formation of airspaces in a solution. A sound wave sent through the liquid compresses the airspaces causing a scrubbing action against the film.

493 – 2. It is a combination of vibrational energy and a liquid solution.

494 – 1. Cause the film not to advance properly.

494 – 2. A flat spot will develop on the roller and the pigment in the titling tape will stick to the heated type.

495 – 1.

a.

Cause	*Correction Measure*
Drive belt defective or missing.	Install good drive belt.

b.

Cause	*Corrective Measure*
Friction brake adjusted improperly or the brake is defective.	Adjust brake or replace defective part of brake assembly.

c.

	Cause	*Corrective Measure*
(1)	Sensing arm not in indicated position.	Position sensing arm so that roller rides on edge of film.
(2)	Sensing arm potentiometer not adjusted correctly.	Adjustment potentiometer.
(3)	Sensing arm loose on shaft or aligned improperly.	Align arm.
(4)	Sensing arm potentiometer or wiring defective.	Replace potentiometer (R2) or repair wiring.

496 – 1. To prevent getting the photographic material dirty. Secondly, dust and lint accumulated on moving parts, bearings, etc., can retard their ease of movement.

496 – 2. To decrease the friction which is produced between two surfaces. Such friction builds up heat, makes movement more difficult, and creates wear.

497 – 1. These flakings could adhere to film being titled. If sufficient friction were applied, this material might cause abrasions.

497 – 2. The flakings from titling tape will build up on the rollers. When there is sufficient buildup, physical damage to the film might result.

497 – 3. Most cloth produces lint. If the rollers are dried with a cloth, there is a chance that the lint will become imbedded in the tacky rollers.

CHAPTER 8

498 – 1.
- a. To detect any condition that causes streaks in the imagery.
- b. To locate conditions that cause physical degradations to be imparted to either the original negative or to the duplicating material.
- c. To insure that the printer is not distorting or degrading the information contained on the ON during printing.

499 – 1.
- a. Nonuniform printing aperture illuminance.
- b. The film transport rate is not consistent.

500 – 1.
- a. To evaluate the dimensional accuracy of the reproduction.
- b. To provide subjective evaluation of slippage.
- c. To determine if the frisket has been properly exposed and processed.

501 – 1.
- a. The standardization frisket is traveling faster than the raw stock. This results in photographic distances in the direction of film travel being decreased on the duplicate product.
- b. The raw stock is traveling faster than the standardization frisket. This results in photographic distances in the direction of film travel being increased on the duplicate product.
- c. This indicates that one of the materials is being transported faster than the other. This will probably result in unsharp as well as elongated images in the direction of film travel.

502 – 1. Install the correct lens, align the camera, adjust the image size, focus the camera, and position the condenser system.

503 – 1.
- a. One roll of raw stock is used in order to minimize the variability of the test procedure introduced by the photographic material.
- b. Since the film surrounding the step tablet will have maximum density, the amount of footage exposed per test should be kept to a minimum to minimize the bromide buildup in the developer when the test material is processed.
- c. The test from all production printers are sandwiched between these two test exposures. The tests from the standard printer are compared for evidence of inconsistent aging.
- d All latent images deteriorate immediately after exposure. However, this deterioration levels off after approximately 1 hour. The aging process is allowed to insure the approximate amount of deterioration for all tests.

504 – 1. Something is wrong with the printer; either transport rate or lamp output is at fault. Maintenance personnel must insure that these are corrected on the standard printer before further tests are conducted.

504 – 2. High densities.

505 – 1.
- a. Adjust spindles and support brackets.
- b. Adjust torque controls.
- c. Thread negative and raw stock.
- d. Insert masks.
- e. Adjust variable neutral-density wedge.
- f. Position the ultraviolet transmitting filter.
- g. Adjust printing lamp intensity.

505 – 2. Eight minutes.

505 – 3. To allow lamp stabilization.

506 – 1. a, c, e.

506 – 2. Set lamp voltage to maximum before turning POWER ON.

507 – 1. The 9.5-inch film roll is heavier than the 70-mm roll. Therefore, additional torque must be applied for proper drag.

507 – 2. The spindles and brackets are adjusted according to material width. This is to position all material in the center of the transport rollers and expose illumination whenever possible.

21.

508 – 1. The buildup of mercury inside the exposing lamp will decrease effective exposing illumination.

508 – 2. The lamp intensity meter will lock and the failure lamp will go on. To correct this situation, the illumination must be brought up to tolerance, the meter unlock button depressed, and the

meter restored to zero by adjusting the printing lamp intensity control knob.

508 – 3. Exposure will be inconsistent, resulting in varying duplicate densities.

509 – 1. The transport is assembled on the face of the rigid plate in the top unit, with motors, power packs, and dust collecting units mounted on the back of the plate.

509 – 2. It is constructed with drawers and a cabinet for storage of accessory items. The printer is set on locking casters.

510 – 1. The splice was not properly made.

510 – 2. Inertia will cause the supply to continue feeding film off the roll.

510 – 3. The printing drum does not turn during slewing. Therefore, the original film will be scratched.

511 – 1. The torque motors would not be energized and inertia might cause the material on the reels to unwind.

511 – 2. Because additional time will be required to allow the printing lamp to cool and to restabilize. This could cause mission failure.

512 – 1.
- a. Eight minutes after turning the main power switch on, the lamp ready light fails to glow.
- b. Eight minutes after turning the main power switch on, the lamp ready light fails to glow.
- c. Printer shuts down during operation. No pilot light glows.
- d. No pressure roller alarm can be heard when main switch is off and pressure roller is down.

513 – 1.

a.

	Probable Cause	*Corrective Action*
(1)	Dirt on calibrated wedge.	Clean the wedge.
(2)	Nickel printing drum or rollers.	Repair drum or rollers.
(3)	Film threaded improperly.	Thread material correctly.
(4)	Dirty film transport components.	Clean.
(5)	Lamphouse mirror(s) dirty.	Clean mirror(s).
(6)	Mercury-arc lamp orientation incorrect.	Reorientate lamp.

b.

	Probable Cause	*Corrective Action*
(1)	Film tension not properly adjusted.	Set torque controls as prescribed.
(2)	Pressure roller out of adjustment.	Adjust pressure roller tension.

c.

	Probable Cause	*Corrective Action*
(1)	Spindle heads located at different distances from the mechanism plate.	Readjust spindles.
(2)	Idler rollers binding.	Repair.
(3)	Pressure roller not contacting the film properly.	Adjust pressure roller.

514 – 1.
- a. If dust is allowed to accumulate inside the lamp housing, it can affect the light intensity of the printing lamp, as well as feedback to the solar cell. When this happens, the printing exposures will be wrong.
- b. The variable neutral density wedge should be cleaned to preclude buildup of dust. Dust also affects printing exposure and may result in varying densities across the film width.
- c. Accumulation of dust, dirt, film chips, etc., can decrease the effectiveness of the vacuum system. This subsequently results in all dust not being removed from the film during printing.
- d. Accumulation of dust might result in the inducers arcing, damaging the unit and decreasing its cleaning effectiveness. If this happens, dust will remain on the materials during printing and the duplicate products will have clear areas where the dust decreased exposure.
- e. Dirty roller and printing drum surfaces could cause scratching and marring of the negative and raw stock materials.

515 – 1.
- a. If the battery is bad the buzzer will not sound to warn you that the pressure roller is in contact with the printing drum when the main power switch is OFF. This will result in a flat spot being formed on the pressure roller.
- b. The material might mistrack during printing.
- c. Improper lamp placement will obstruct the illumination in the printing area.

516 – 1.
- (1) c.
- (2) d.
- (3) e.
- (4) b.

516 – 2. A 10-inch diameter illuminized CRT.

517 – 1. Additive-type color printers employ dichroic mirrors to split the white light beam into the primary colors. These individual light beams are then modulated and recombined to produce the exposing illumination.

517 – 2. In the subtractive-type printers, filters of the secondary primary colors are used to subtract quantities of the primary colors from a single exposing light source.

518 – 1. Since each primary color is controlled by neutral density filters, more neutral density filtration should be placed in the red light beam.

518 – 2. Probably the tape was not programmed to stop the printer operation at the end of the last scene.

518 – 3. The heat filters probably were not positioned in the exposing light path.

518 – 4. Change the trimmer setting to compensate for the variations in color balance between the two films.

519 – 1. The fader is closed or the roller gate is open.

519 – 2. Probably, the cue actuating roller is not positioned so that it rides on the edge of the film.

519 – 3. No tape is present in the reader, or tape is present but fader is closed.

519 – 4. The edge printer switch was not turned on.

519 – 5. The tape has been moved or set at an erroneous position relative to the first row of holes in the tape and the readout pins of the reader.

520 – 1. To position the neutral density filter in the integrated light beam.

520 – 2. The color beams must be rebalanced.

520 – 3. The tape was programmed with fades which also caused the sound to fade.

520 – 4. First, the air supply used to cool the printing lamp, keep the aperture clean, and provide better contact of the materials was not being filtered. Second, the filter could have been in place, but dirty.

521 – 1. Either a power failure occurred or the main power or AC switch was momentarily turned off.

521 – 2. Probably the manual fade button was accidentally depressed.

521 – 3. The air inlet or exhaust vents on top of the van housing are closed.

521 – 4. The film was probably cued with notches. Notches will not cue the printer when the selector switch is in the RF position.

522 – 1. a. Dust will probably adhere to the film during subsequent printing, causing pinholes, etc.
b. Not exhausting the heated air will decrease the useful life of the exposing lamp.

523 – 1. a. Switch improperly adjusted; defective notch cue switch; open circuit to switch.
b. Open circuit, defective motor.
c. Defective counter; defective switch S501 in fader.

524 – 1. To maintain peak operating efficiency.
524 – 2. The number of operating hours, the number of cues, or both.
524 – 3. Keeping the equipment clean.

525 – 1. a. A burr, which will physically damage the original or duplicating material, might be produced on the roller.
b. The face is plastic. Using a chemical cleaner might result in the face being scratched or dissolved.
c. The mirrors might be damaged, resulting in decreased effectiveness in reflecting only one primary light color.

CHAPTER 9

526 – 1. a. Dissolve.
b. Wipe.
c. Fade.
d. To provide a transition between scenes.
e. At the beginning and end of a film, to separate titles from the first action, to separate scenes, and to create dramatic breaks.
f. To bridge a lapse of time, to provide a space or action transition, to separate a series of titles, and to provide a change of pace from the usual scene-to-scene cuts.
g. To lead action in or cut out of the scene, to introduce a new or opposing thought, to separate related but confusing thoughts, to shorten a verticle pan, to create the feeling of a stage curtain, and to give the feeling of ascending or descending.

527 – 1. The act of determining the correct exposure for each scene.
527 – 2. Programmed punch tape or by notching the film.

528 – 1. Red = 7, Green = 26, Blue = 5.
528 – 2. Red = 24, Green = 12, Blue = 7.
528 – 3. Red = 24, Green = 24, Blue = 15.
528 – 4. Red = 21, Green = 10, Blue = 28.

529 – 1. a. The patches probably would be removed.
b. The patch is not of sufficient size to trigger the printer.
c. The patches will not trigger printer changes.

530 – 1. a. Patches.
b. No cues are received by the printer.
c. Both patches and notches.
d. Both patches and notches.

531 – 1. In order that all even- or odd-numbered scenes might be on the same printing roll.
531 – 2. A length of black leader is spliced between each scene. The length of the leader is equal to the length of the scene that will be printed at that location.

532 – 1. During printing, portions of the A and B rolls will be superimposed.
532 – 2. The soundtrack will not match the print.

533 – 1. To hide minor base scratches on the film.
533 – 2. By filling in the scratches with a solution that is of the same refractive index as the film base.
533 – 3. No. Only the base of the film.

AU GAFS, AL. (854243)600

STOP-
1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 03 23

CONTINUOUS IMAGERY PRODUCTION

Carefully read the following:
DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (400) How is the inspection of panchromatic or infrared emulsions performed?

   a. In subdued light conditions.
   b. In total darkness.
   c. Under a red safelight.
   d. Under an amber safelight.

2. (402) Which of the following is a result of neglecting to repair a torn film edge during preinspection?

   a. Excessive solution agitation.
   b. Decreased mission handling time.
   c. Tearing of the film.
   d. Overheating of the chemistry.

3. (403) Which of the following is *not* a film splicing requirement?

   a. The splice must be made with "Mylar" tape.
   b. The splice must be durable in the wet state.
   c. The splice must be capable of withstanding movement.
   d. The splice must be durable in the dry state.

4. (403) Select the correct statement concerning the tape-heat method of splicing film.

   a. Temperature too high--film will probably separate during processing.
   b. Temperature too low--the spliced area will contain wrinkles.
   c. Temperature too high--film may blister near the splice.
   d. Temperature too low--splice will be too thick.

5. (404) During startup procedures, what is the correct water flow rate for the Versamat processor?

   a. 0.10 gallons per minute.
   b. 0.5 gallons per minute.
   c. 5 gallons per minute.
   d. 10 gallons per minute.

6. (405) If a developing time of 2.5 minutes is needed for film being processed in a machine which contains 32 feet of film in the developing tanks, the transport speed must be

   a. 6.4 fpm.
   b. 8 fpm.
   c. 12.8 fpm.
   d. 16 fpm.

7. (406) The prime consideration when establishing wash water flow rates for continuous processors is that the

   a. wash water be free of all chemical salts.
   b. flow rate be sufficient to insure archival quality.
   c. wash water be 80°F.
   d. flow rate be excessive to insure thorough washing.

8. (407) The type of developer used in black-and-white continuous processing is

   a. determined by the processing machine used.
   b. dependent upon desired gamma and density.
   c. determined by the type of material being processed.
   d. dependent upon the required solution temperature.

9. (408) Which of the following is *not* a reason for producing the best possible photographic image?

   a. So that complete interpretation is possible.
   b. So that intelligence information can be retained during printing.
   c. So that intelligence information may be enhanced during printing.
   d. So that duplicating speed may be as short as possible.

10. (409) The speed of the developer reaction is primarily dependent upon

   a. temperature.
   b. agitation.
   c. the amount of preservative in the developer.
   d. the amount of reducing agent in the developer.

11. (410) Dirt particles can enter the processing system during all of the following *except*

   a. solution replenishment.
   b. film entry into the machine.
   c. solution recirculation.
   d. heating and cooling of the solution.

12. (411) Which of the following replenishment methods is most often used for continuous processing and offers the most advantages?

   a. The recirculation method.
   b. The bleed method.
   c. The intermittent method.
   d. The topping-up method.

13. (412) Which choice describes replenishment charts, as used in continuous processing?

   a. Contain measures for automatically compensating for over and under exposure.
   b. Based on solution temperature and machine speed.
   c. Accurate and must not be changed.
   d. Based on machine speed and film width.

14. (414) The exact temperature limits for material drying during continuous processing are governed by all the following *except*

   a. the kind of material being dried.
   b. how the material was processed.
   c. the operating speed of the processor.
   d. the type of dryer being used.

15. (415) Air squeegees may be used between two tanks containing different solutions only

   a. to maintain correct solution temperatures.
   b. if the air striking the surface of the film does not oxidize the solutions.
   c. if the air squeegee is operating at a low air pressure.
   d. when used with an air compressor that uses oil lubrication.

16. (416) During wide film splicing, what happens when the access door handle is turned to the CLOSED position?

   a. The film lock opens, stopping the film.
   b. The film lock opens, allowing the film to pass through.
   c. The film lock closes, stopping the film.
   d. The film lock closes, allowing the film to pass through.

17. (417) When splicing narrow film using the stapler, the film ends should be overlapped approximately

   a. 3-1/2 inches.
   b. 2-1/2 inches.
   c. 1-1/2 inches.
   d. 1/2 inch.

18. (417) What would happen during processing if the trailing end of spliced narrow film was on bottom?

a. The edge of the film will probably snag, breaking the film.
b. The edge of the film will probably snag and stick in the machine.
c. The edge of the film will probably snag, stopping the machine.
d. Nothing; the splice was made correctly.

19. (418) The primary difference between the wide film and narrow film processors is the

a. speed at which they transport the material through the solution.
b. maximum solution temperature they will maintain.
c. threading pattern designed into the unit.
d. type of dryer used to dry the materials.

20. (419) The "flash film" processed during processor certification is most often used to

a. check for processor produced scratches and abrasions.
b. insure that the developer will produce an image.
c. establish replenishment rates.
d. establish printer exposure levels.

21. (420) What would probably be the cause of drying streaks produced during mechanical certification of black and white processors?

a. Developer temperature too high.
b. Water temperature too low.
c. Improper squeegeeing or blocked airflow in drying compartment.
d. Airflow velocity too high.

22. (422) During machine certification, it can be assumed that the processor is certified when the flash film has been processed and analyzed, the chemicals meet pH and specific gravity standards, and when

a. the sensitometric data are within control standards.
b. the process gamma from the first sensitometric strip plots anywhere within the control limits.
c. the process gamma is within ± 0.10 of the desired gamma.
d. a minimum density of 0.35 is obtained on the sensitometric strip.

23. (422) What action should be taken when a processor will *not* certify chemically?

a. Let another operator try to certify it.
b. Drain the old processing chemicals.
c. Dump the pH buffer used during the test.
d. Recalibrate the sensitometer and densitometer.

24. (423) A chart which visually displays data in the order of occurrence is called

a. an occurrence chart.
b. an incident chart.
c. a control chart.
d. a display chart.

25. (424) The most important factor in a specific gravity determination is

a. extreme accuracy.
b. repeatability.
c. temperature of the solution.
d. concentration of the solution.

26. (424) pH is defined as the

a. negative logarithm of the effective hydroxyl ion concentration.
b. positive logarithm of the effective hydroxyl ion concentration.
c. negative logarithm of the effective hydrogen ion concentration.
d. positive logarithm of the effective hydrogen ion concentration.

27. (426) The photographic quality of black-and-white products is usually measured in terms of

a. density and abrasions.
b. density and contrast.
c. contrast and gamma.
d. gamma and abrasions.

28. (427) A decrease in color density with no significant change in color balance can be caused by all of the following *except*

a. first developer temperature too high.
b. prehardener temperature too low.
c. first replenishment rate too low.
d. the shelf life of the first developer replenisher has been exceeded.

29. (428) What occurs during overreplenishment of any developer solution?

a. An increase of the pH of the solution.
b. An increase of the specific gravity of the solution.
c. A decrease of the pH of the solution.
d. A decrease of the specific gravity of the solution.

30. (429) The two main disadvantages of the spray processing system are the cost of the equipment and the

a. precise control of solution temperatures required.
b. large volumes of solutions used.
c. continuing adjustments necessary for the spray fans.
d. decreased material transport speed possible.

31. (430) All the following are steps that might be required for original negative processing before the material is released *except*

a. assembly.
b. inspection of processed material.
c. titling.
d. editing.

32. (431) The major disadvantage of the immersion-type processing system is

a. its inability to produce repeatable results.
b. the large volume of processing chemicals required.
c. the accumulation of foreign matter in the solution tanks.
d. that this system is somewhat slow.

33. (432) If maximum solution agitation is *not* provided the film during immersion processing, what is the probable result?

a. The film will have a high density.
b. The film will have a low density.
c. The film will be developed evenly.
d. The film will be developed unevenly.

34. (433) As original negative film is duplicated, each generation becomes progressively worse because of

a. increased image acutance.
b. increased density differences.
c. decreased image resolution.
d. decreased subject contrast.

35. (433) The visual appearance of duplicate photographic products can be improved

a. by increasing the density range.
b. by processing to a gamma of 1.00.
c. through chemical control of the process.
d. through sensitometric control of the process.

36. (434) To determine the exact process gammas needed is simply a matter of

a. multiplication.
b. addition.
c. division.
d. subtraction.

37. (435) During reversal color processing, the colored dyes are formed in the proportion to the

a. negative silver image.
b. initial camera exposure.
c. formation of the positive silver image.
d. color developing time.

38. (436) Loop-type threading of continuous processors are most often associated with

a. narrow films.
b. color reversal materials.
c. spray processing systems.
d. aerial reconnaissance films.

39. (437) All the following are requirements for making film running splices *except*

a. the splice must be durable in the wet state.
b. the splice should not be appreciably thicker than the film itself.
c. the trailing edge of the film must be overlapped by the leading edge.
d. the splice must be durable in the dry state.

40. (438) If a processor is operating at 40 fpm, and its accumulator section holds 10 feet of film, what is the maximum time available for making a splice?

a. 1 minute.
b. 57 seconds.
c. 25 seconds.
d. 15 seconds.

41. (439) In order to repair a break in a narrow film being processed such as 16mm motion picture film, you should use

a. masking tape.
b. mylar tape.
c. stainless steel staples.
d. waterproof adhesive.

42. (440) Probably the most valuable sense used in determining processor malfunction is

a. smell.
b. touch.
c. hearing.
d. sight.

43. (440) Which of the following is *not* important in determining a processor malfunction?

a. Sight.
b. Hearing.
c. Touch.
d. Smell.

44. (441) What is the greatest responsibility that rests upon the operator of a continuous film processor?

a. To insure the machine is ready to process film at a moment's notice.
b. To salvage as much film as possible if a film break occurs.
c. To ensure that a machine can be certified in record time for film processing.
d. To personally make all mechanical repairs of the machine.

45. (442) All of the following material defects are caused by improper drying compartment monitoring *except*

a. reticulation.	c. underdrying.
b. drying streaks.	d. overdrying.

46. (442) The *primary* reason for monitoring a processor during operation is to

a. keep the system performing at its optimum capability.
b. ensure that material drying is sufficient.
c. maintain a constant material transport speed.
d. ensure acceptable material density and contrast.

47. (443) Crystallized chemicals found on the material after processing can only be caused by

a. improper washing.	c. improper mixing of the solutions.
b. solution temperature too low.	d. dryer air jets clogged.

48. (444) When all material processing has been completed, the operator should

a. run another sensitometric strip through the processor.
b. dump the processing chemicals and refill the tank with fresh solutions.
c. prepare the machine for processing the next mission film.
d. insure sufficient replenisher is available for subsequent processing.

49. (444) The temperature that is considered as being safe to turn off the drying compartment blower is

a. 100° to 110° F.	c. 120° to 130° F.
b. 110° to 120° F.	d. 130° to 140° F.

50. (445) The main reason for insuring that replenisher line valves are fully closed during processor shutdown periods is

a. that otherwise too much replenisher solution would be used.
b. to maintain chemical balance.
c. to prevent a drastic decrease in developer pH.
d. to decrease the manhours used in mixing chemicals.

51. (446) Improperly accomplished processor shutdown procedures could result in all the following *except*

a. decreased life expectancy of the processor.
b. a change in processing chemistry composition.
c. elongated scratches on the film.
d. burned out dryer heating elements.

52. (447) Troubleshooting a continuous processor is that task which evaluates the performance of the processor in terms of operation and

a. product quality.	c. chemical defects.
b. physical defects.	d. chemical quality.

53. (448) What would cause black spots on the film during Versamat black-and-white processing?

a. Metal burrs on the feed tray.
b. Transport rollers dirty.
c. Silver build-up on the rollers in the developer racks.
d. Crossover rack encrusted with a heavy layer of chemical deposits.

54. (449) All the following factors are considered before the Air Force procures a piece of equipment *except* the

a. type product to be handled.
b. speed at which the product is to be produced.
c. desired product characteristics.
d. cost of the equipment.

55. (451) Each time the Versamat 11C-MW is shut down, you must

a. change the developer recirculation line filter.
b. recharge the processor with fresh solutions.
c. rinse all crossover assemblies.
d. decrease the drying compartment temperature to 125°.

56. (453) Season the developer tanks of a processor after cleaning to

a. neutralize the cleaning solution.
b. prevent the formation of dichroic fog on film.
c. charge the new developer recirculation line filter.
d. test the drain valve and recirculation lines for leaks.

57. (454) The suggested method for cleaning the prehardener racks of the color Versamat is with

a. system cleaner.
b. warm water.
c. a 10-percent solution of sodium hydroxide.
d. glacial acetic acid.

58. (455) Cleaning of the processor replenishment and recirculation system should

a. be accomplished by using Kodak System Cleaner.
b. precede the cleaning of the processor solution tanks.
c. be accomplished when the processor is on extended shutdown status.
d. be accomplished after the processor's solution tanks have been cleaned.

59. (456) Corrosion control of stainless steel can *best* be accomplished by

a. blasting lightly.
b. immersion in chromic acid.
c. using sodium hydroxide base cleaner.
d. immersing in a solution of warm water and household detergent.

60. (458) All the following are advantages of the Viscomat processor *except*

a. use of less floor space.
b. fast access of the photographic product.
c. solution spray application system.
d. choice of solution systems.

61. (459) The total time for Viscomat operation from dry to dry when using normal (two-solution) processing is

a. 121 seconds.
b. 60.5 seconds.
c. 45 seconds.
d. 22.5 seconds.

62. (461) The papers used in the Electrofax process are coated with a photoconducting material called

a. resin.
b. zinc oxide.
c. alumina oxide.
d. sulphur dioxide.

63. (462) In comparison to a regular silver process, the dry silver process uses

a. 1/10 to 1/20 the amount of silver.
b. 1/25 to 1/35 the amount of silver.
c. 1/50 to 1/60 the amount of silver.
d. 1/75 to 1/85 the amount of silver.

64. (462) Dry silver material are exposed by

a. static electricity.
b. fluorescent lamps.
c. conventional printers.
d. the infrared process.

65. (463) Which of the following statements concerning the diffusion transfer process is *true*?

a. This process is relatively slow.
b. The unexposed silver halides are dissolved as the negative image is being produced.
c. During development, the exposed silver halides are transferred to the print material.
d. No chemical reaction takes place within the print material during print production.

66. (464) What is the cause of a Polaroid print being too light?

a. Overexposure.
b. Overdevelopment.
c. Underexposure.
d. Underdevelopment.

67. (465) Separating the long processing rolls into individual rolls as produced by the camera is the task accomplished during

a. secondary breakdown.
b. primary breakdown.
c. original breakdown.
d. duplicate breakdown.

68. (466) Densitometric evaluation of aerial roll material is the basis for

a. duplicate breakdown.
b. primary breakdown.
c. secondary breakdown.
d. original breakdown.

69. (467) Any original negative footage that is *not* considered a part of the mission is termed

a. cloud cover.
b. target alignment material.
c. mission support footage.
d. clearance frames.

70. (469) The usual method of splicing head and tail leader strips to aerial roll film is with

a. film cement.
b. "Mylar" type tape
c. a heat splicer.
d. an ultrasonic splicer.

71. (469) When attaching friskets to the original negatives, the negative must be wound so that

a. the first exposure made is on the outside of the roll, emulsion down.
b. the last exposure made is on the outside of the roll, emulsion down.
c. the first exposure made is on the inside of the roll, emulsion up.
d. the last exposure made is on the inside of the roll, emulsion up.

72. (470) Which of the following is *not* a requirement for splices joining leader strips to mission roll film?

a. The splice must be durable in the dry state.
b. The splice must join the leader material to the film squarely.
c. The splice must be durable in the wet state.
d. The splice must be flexible.

73. (471) The information to be included on the head and tail friskets for aerial reconnaissance film is set forth in

a. AFM 50-5.
b. AFM 55-5.
c. DIAM 50-5.
d. DIAM 55-5.

74. (473) The process of making several printing runs at different exposure levels in lieu of rearranging the material is called

a. strip-printing.
b. repeated-printing.
c. sequence-printing.
d. split-printing.

75. (474) Concerning startup of the dual-head titler, heater controls should be set to their maximum settings for a period of

a. 3 minutes.
b. 5 minutes.
c. 10 minutes.
d. 15 minutes.

76. (476) What action should be taken when the pigment imprint appears to be fuzzy?

a. Increase the titling head heat.
b. Reduce the titling head heat.
c. Increase the air pressure.
d. Reduce the air pressure.

77. (477) What part of the titler is considered a pneumatic device?

a. The titling heads.
b. The rewind spindles.
c. The directional switch.
d. The main timer.

78. (478) Proper titling pressure is achieved when the

a. pressure gages indicate maximum pressure.
b. film is not embossed.
c. titling tape advances one-half inch after transfer.
d. title is legible without the film being embossed.

79. (481) During titling, if superimposing of characters on the titling tape occurs, the operator should

a. increase the air pressure to the titling head.
b. increase the air pressure to the counter pad.
c. advance the titling tape by turning the tape advance knob.
d. move the stops on the tape advance can farther apart.

80. (481) What will result if the heat from the titling head is allowed to soften the titling tape pigment?

a. The pigment will flow.
b. The tape will flake.
c. The film will be embossed.
d. The tape will be superimposed.

81. (484) The only cam on the dual-head titler that should be regulated by the operator is the one which controls

a. indexing.
b. printing cycle.
c. tape advance.
d. film advance.

82. (485) When using the dual-head titler, the printing cycle will repeat if the

a. foot switch is not released as soon as the lower cylinders advance.
b. indexing cams are out of synchronization.
c. COUNTER and TYPE pad air pressures are too great.
d. titling tape does not advance sufficiently to prevent superimposition.

83. (486) What happens if the Tacoma titler looses power?

a. An 8-minute warmup period must be restarted.
b. A battery backup will be activated.
c. The DC power switch must be turned on.
d. The exposure meter will have to be reset after power resumes.

84. (487) The Houston Fearless Corporation's Tacky Roller Film Cleaner includes a

a. film lacquering roller.
b. liquid immersion film cleaner.
c. static electricity remover.
d. dust removal vacuum device.

85. (489) When is constant Tacky Roller transport speed assured?

a. Only when the sensing arm rests against the film roll on the takeup side.
b. When the transport speed control knob is locked at the desired speed.
c. When the sensing arm is properly positioned against the supply roll.
d. Only when the roll length is greater than 200 feet.

86. (490) During Tacky Roller Film Cleaner operation, what could cause the transport mechanism to operate but the film to *not* transport?

a. The sensing arm has not been properly positioned.
b. The takeup spindle brackets have not been properly positioned.
c. Too much torque on the supply roll.
d. The tacky rollers are too damp and the material sticks to them.

87. (491) Which of the following statements describes the actual transport speed needed to clean film on the Tacky Roller Film Cleaner?

a. Speed is 38 feet per minute.
b. Speed varies with the width of the film.
c. Speed is dependent upon the physical state of the film being cleaned.
d. Speed varies with the relative humidity of the surrounding area.

88. (492) What happens when the Tacky Roller Film Cleaner is operated without the static eliminator unit being activated?

a. The cleaner will not remove all the dust from the film.
b. The transport speed will be slightly increased because of the increased voltage to the transport motor.
c. A potential electrical hazard exists for the operator.
d. The cleaned film will attract airborne dust and lint from the surrounding area.

89. (493) The *best* explanation of film cleaning by cavitation principles is

a. the rushing in of the cleaning solution to fill vacuums created by ultrasonic sound waves.
b. the formation of airspaces within the cleaning solution.
c. the creation of hydrostatic pressure by the inaudible sound waves.
d. the collapse of the submicroscopic airspaces within the cleaning solution.

90. (494) To prevent flat spots from developing on the rubber-covered tape drive roller when the dual-head titler is not in use, the operator must

a. turn off the air supply to the dual-head titler.
b. place the titler heads in the raised position.
c. be sure the main power is turned off.
d. insure the timer switch is in the OFF position.

91. (496) All the following could be considered preventive maintenance tasks common to all photographic equipment *except*

a. equipment calibration.
b. equipment cleanliness.
c. proper lubrication.
d. cleanliness of the surrounding area.

92. (497) Buildup on the rollers of the dual-head titler most often results from

a. emulsion separating from the film base.
b. titling tape flaking from the titled film.
c. residual processing chemicals remaining in the film.
d. dust, dirt, lint, etc. on the film.

93. (498) Evaluation of illuminance uniformity across the printing aperture is made to detect

a. the actual amount of light reaching the negative.
b. conditions that cause streaks in the imagery.
c. the color balance of the exposing light.
d. decrease in illuminance intensity at the edge of the projected image.

94. (499) All of the following tests must be conducted during printer certification *except*

a. film transport rate test.
b. printing aperture illuminance uniformity test.
c. raw stock crossover test.
d. physical abrasion test.

95. (499) Which of the following would *least* likely result in the duplicate imagery being streaked?

a. Variations in transport speed.
b. Poorly aligned light source.
c. Dirty optics.
d. Oil printer lamps.

96. (500) A printer certification frisket should include all the following *except*

a. resolution targets.
b. reseau marks.
c. half-tone screen.
d. step tablet.

97. (501) If a printer is expected to yield a resolution capability of 200 lines per millimeter, the maximum resolution value of the resolution target would normally be

a. 400 lines per millimeter.
b. 300 lines per millimeter.
c. 250 lines per millimeter.
d. 200 lines per millimeter.

98. (501) The portion of the certification frisket used to evaluate the dimensional accuracy capability of the printer is the

a. resolution targets.
b. step tablet.
c. reseau marks.
d. half-tone screen.

99. (502) With the "Acme 104" printer, you are able to print at a 1:1 ratio because this printer is

a. an enlargement printer.
b. a reduction printer.
c. a contact printer.
d. an optical printer.

100. (503) The amount of footage exposed during the correlation test should be kept to a minimum to

a. preclude film wastage.
b. speed up the testing time.
c. minimize silver buildup in the fixer.
d. minimize bromide buildup in the developer.

101. (503) During evaluation, what happens if it is found that the correlation test reference exposures are different?

a. The standard printer should be standardized.
b. The processor should be recertified.
c. A longer aging period is required.
d. A different type raw stock must be used.

102. (505) After the main power switch is turned on, how long does it take before the Niagara printing lamp is stabilized?

a. 8 minutes.
b. 8 seconds.
c. 5 minutes.
d. 5 seconds.

103. (508) The Niagara three-position voltage selector switch is used only when

a. you want to use the printer during a void condition.
b. the lamp adjust produces too much variation.
c. lamp intensity cannot be maintained with the lamp adjust control.
d. pattern lamps do not afford the proper dodging.

104. (509) Which of the following statements concerning the Niagara printer is *not* correct?

a. The film transport is assembled on the face of a rigid mechanism plate in the top unit.
b. A dust collecting unit is an important part of the printer.
c. The rear access doors are interlocked to remove all power from the cabinet components when the doors are open.
d. The printer should be at a fixed position to preclude damage usually incurred during movement.

105. (511) If the Niagara printer main power switch is turned off and then on again immediately, approximately how long will it take before the printer will be operational?

a. Immediately.
b. 8 minutes.
c. 16 minutes.
d. 24 minutes.

106. (512) During operation, what would probably cause the Niagara to shut down and the pilot light *not* to glow?

a. Solar cell assembly defective.
b. Faulty connector on power cable.
c. Tungsten lamp in lamp house.
d. Printing lamp burned out.

107. (513) All of the following could result in streaks in the material printed on the Niagara *except*

a. incorrect transport tension.
b. dirty calibration wedge.
c. film threaded improperly.
d. lamphouse mirrors dirty.

108. (514) To remove dust from the static eliminator inductor on the Niagara, you should use a

a. vacuum cleaner.
b. lint free cloth.
c. toothbrush.
d. special liquid detergent.

109. (515) The buzzer which warns the operator that the pressure roller is in contact with the printing drum when the Niagara is *not* operating is powered by a

a. 24-volt battery.
b. 18-volt battery.
c. 12-volt battery.
d. 6-volt battery.

110. (516) Which of the following functions of the SP 10/70B will have a degrading effect on resolution during its operation?

a. The breaking action of the drag rollers in the drive system.
b. Y-scale adjustment is set on DW and film is being used.
c. The lucite roller printing plate in contact with printing material.
d. Moving the locking handle to the extreme left.

111. (517) The printers that use the additive system of exposure operate using

a. neutral density and color compensating filters.
b. color printing and color correction filters.
c. three light sources--cyan, magenta, and yellow.
d. three light sources--red, green, and blue.

112. (518) As an optical setting for automatic operation, the trimmers for the 6100C printer should be set on

a. 0.025 log E.
b. 12.
c. 24.
d. 73.

113. (519) Opening the roller gate of the 6100C printer results in all the following *except* the power to the

a. drive motor being cut off.
b. takeup motors being cut off.
c. douser mechanism being cut off.
d. exposing lamp being cut off.

114. (520) The purpose of the accessory soundhead for the 6100C printer is to

a. produce an extra soundtrack if needed.
b. provide a single pass picture and soundtrack capability.
c. allow the soundtrack to be faded along with the picture.
d. change magnetic recording of sound to optical recordings.

115. (521) An original having notch cuing is retimed with RF cues. The 6100C printer cue switch is set at NOTCH-RF and the original bypasses the RF nylon roller. Which of the following is correct?

a. The notches will determine the timing.
b. The system will not operate.
c. Both cuing systems will operate.
d. The reader will not operate in this mode.

116. (522) In order to allow the 6100C lamphousing to cool after all printing operations have been completed, the

a. exposing lamp switch is turned off.
b. AC power switch only is turned off.
c. DC power switch only is turned off.
d. AC and DC power switches must both be turned off.

117. (523) When the lamp and both blowers on the 6100C printer do *not* function, it is probably because

a. an AC circuit is open.
b. the AC input to the printer is low.
c. switch S501 is defective.
d. of an improperly adjusted switch.

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118. (524) In general, the operator's responsibility in the preventive maintenance of the 6100C printer is limited to

a. lubrication.
b. cleaning.
c. transport speed calibration.
d. changing the exposing lamp.

119. (525) Cleaning of the 6100C printer dichroic mirrors should be accomplished

a. at the close of each day's operation.
b. with a high pressure air jet.
c. with an oil moistened diaper cloth.
d. only when absolutely necessary.

120. (526) A length of film where one scene gradually loses intensity while another gains intensity at the same time is called a

a. wipe.
b. fade.
c. matte.
d. dissolve.

121. (527) In motion picture photography, determining the proper printing exposure for each scene is the function best known as

a. timing.
b. editing.
c. programming.
d. matte production.

122. (528) In tape programming, the desired lighting changes are punched into the tape and the activation of the change is done by

a. an edge notch.
b. a stop start tape hole.
c. a film footage counter.
d. the tape reader.

123. (529) The most common cue system on the 6100C printer is the

a. notch type.
b. RF type.
c. NOTCH-RF type.
d. metallic patch type.

124. (531) Probably the most critical step in editing motion picture film is

a. timing.
b. cuing.
c. cutting the work print to match the release print.
d. cutting the original negative to match the work print.

END OF EXERCISE

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MAIL TO: ECI, GUNTER AFS AL 36118-5643

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package. and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

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5. SOCIAL SECURITY NUMBER (7-15) – –	6. GRADE/RANK	7. NAME (First initial, second initial, last name) (17) – (18) – (19-32)	
8. ADDRESS OJT ENROLLEES Address of unit training office with zip code. ALL OTHERS Current mailing address with zip code.	(33-53) (54-75)		
9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE		10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-39)	

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5	Correct SSAN. *(List incorrect SSAN here.)* *(Correct SSAN should be shown in Section I.)*			
6	Extend course completion date. *(Justify in "Remarks")*			
7	Request enrollment cancellation. *(Justify in "Remarks")*	16 G	33	
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 10 Originals were: [ ] Not received [ ] Lost [ ] Misused	K	VOL 33-35	GR 36-38
9	Send course materials. *(Specify in "Remarks")* [ ] Not received [ ] Lost [ ] Damaged	M	33-34	35-40
10	Course exam not yet received. Final VRE submitted for grading on ____________ (date).	N	33-35	
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received. Answer sheet(s) submitted ______________ (date).	P	VOL 33-35	
12	Results for CE not yet received. Answer sheet submitted to ECI on ____________ (date).		TC 36-37	38
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15	Other *(Explain fully in "Remarks")*		MC 39-42	

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CDC 23350

IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

Volume 4A

Chemical Analysis and Process Control

Extension Course Institute
Air University

411

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Preface

IN THIS VOLUME of CDC 23350-04A, *Imagery Production Specialist,* we discuss the use of good laboratory equipment and the knowledge of how to use it to make possible the accurate weighing and measuring of chemicals.

The imagery production specialist must keep a finger on the pulse of the imagery processing facility through daily inspection checks of the processing solution and the finished imagery produced. Test strips from sensitometric printers are read frequently. Daily checks on pH content of all processing solutions are routine in many laboratories.

Chapter 1 covers various items of laboratory apparatus, how to use them, and how to take care of them.

Chapter 2 discusses the preparation of solutions used in precision processing facilities and the accuracy and controlled conditions needed for certifying these solutions before they are used in the laboratory.

Chapter 3 covers the quantitative analysis of photographic chemicals and how an analysis is used. We also discuss the preparation and use of analytical reagents and indicators and how molar, normal, and percentage values are determined. You also will study the quantitative determination of chemicals used in the photographic solutions.

Chapter 4 covers the use of chemical analysis to establish replenishment programs, make corrective additions to solutions, and certify solutions.

Code numbers appearing on figures are for preparing agency identification only.

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This volume is valued at 39 hours (13 points).

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Laboratory Equipment and Procedures

IN IMAGERY processing you must use chemicals in the proper quantities. You have good laboratory equipment, but you must know how to use it to accurately weigh and measure the chemicals used in the imagery/production laboratory.

In this chapter, we will discuss various items of laboratory apparatus, how to use them, and how to take care of them. To go into how quantities are determined, we must treat the chemistry involved and the laboratory equipment used to mix and certify these solutions before their use. Later when you wish to determine the effectiveness of the same solutions used in the processing laboratory, you may use similar equipment and procedures.

In a large laboratory, the chemical control may be assigned to a small unit rather than divided between the chemical-mix section and the processing section. The equipment used may range from the simple hydrometer to the complex ultraviolet spectrophotometer. The former instrument is used to check whether all ingredients have been mixed into a photographic solution. The latter measures the absorptive qualities of a solution or a particular ingredient within the solution. The precision measurements obtained by these typical laboratory apparatus is dictated by the kinds of imagery processes being carried out and the degree of chemical control required. First, let's look more closely at the hydrometer.

1-1. Hydrometer

The hydrometer is a relatively simple piece of laboratory apparatus used primarily to measure the specific gravity of a solution. Specific gravity refers to the relative density of a solution. In photography, individual solutions are made up of many different solutes so that a mixed solution is extremely difficult to analyze chemically. One of the quickest checks to see if all of the chemical ingredients have been mixed into a solution is to measure specific gravity.

600. State the purpose, the determination of general standards, and the indications to be gained from the reading of the specific gravity of a solution.

Specific Gravity. Specific gravity is the ratio of weight of any substance (or solution) to the weight of an equal volume of some substance that acts as a standard. The standard used to measure the specific gravity of solids and liquids is distilled water; air or hydrogen is used to measure specific gravities of gases. The measurements are made at the same temperature or at stated temperature.

The *absolute specific gravity* of solids and liquids is the ratio of the weight of a given volume of the material at a stated temperature (and weighed in a vacuum) to the weight of an equal volume of gas-free distilled water at a stated temperature (and weighed in a vacuum).

The importance of specific gravity is that it can be measured rapidly, provides a reasonably accurate check on solution concentration, and can be performed with relatively simple equipment. If the same chemicals in the same quantities are dissolved in the same amount of water each time a solution is prepared, the specific gravity of the solution will be the same each time the solution is prepared. Specific gravity, then, becomes a characteristic of the particular solution at a specific temperature.

A quick check of the specific gravity of a newly prepared batch of solution will tell you whether or not the solution merits further testing. By comparing the specific gravity reading with the standard specific gravity for this same solution, you have a rough indication that all of the constituents have been (or have not been) added and that the relative amounts of water and combined solutes are (or are not) correct.

The specific gravity for a particular solution should stay within an upper limit and a lower limit. That is, through the maintenance of records and through the inspection of the products produced, you can accurately determine what the specific gravity of a given solution should be. You can also learn how far the specific gravity of a given solution can vary from deterioration of the imagery product. Variations beyond the upper limit or beneath the lower limit then becomes indicative of a substandard solution. If the specific gravity is too high, the indication is that the solution contains too much chemical, the wrong chemical, or too little water. If the specific gravity is too low, the indication is that the solution contains too little chemical, the wrong chemical, or too much water.

The specific gravity for a given solution can be established at the start by preparing the solution as accurately as possible. When the solution is prepared, measure and record the specific gravity. When the solution is used, carefully check the results that are produced through visual quality control and through sensitometric

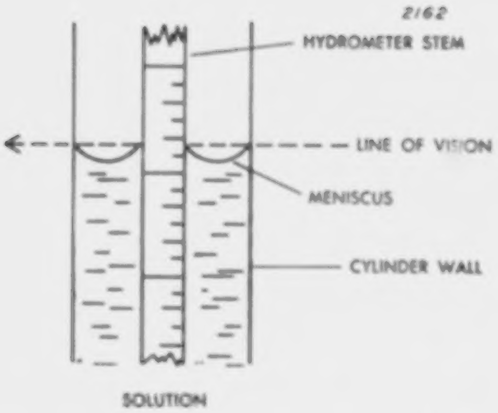

Figure 1-1. Reading a hydrometer correctly.

quality control. If the results prove to be satisfactory, this specific gravity can then be used as a beginning standard. With each subsequent batch of solution prepared, record the specific gravity and the quality of the product produced. When sufficient data are accumulated, you can apply statistical control methods to the data. From this point on, if you run a specific gravity test on a new batch of processing solution and if the test falls within established tolerances, you can be reasonably sure that the solution has been prepared accurately enough to justify further testing. (The specific gravity test is normally the first test made on a newly prepared batch of solution.)

Exercises (600):

1. You have prepared a new batch of solution and want to know whether or not the solution merits further testing. What procedures should you follow?

2. How can you determine what the specific gravity of a given solution should be?

3. If a specific gravity test falls within established tolerances, what can you reasonably assume about the preparation of the solution?

601. State how to determine the specific gravity of a substance or solution.

Methods of Determining Specific Gravity. Specific gravity of a solution can be determined in various ways. However, we will limit ourselves to two methods: determining specific gravity by weight and determining specific gravity with a hydrometer.

When you want to determine specific gravity by weight, you normally use a density or specific gravity bottle. A specific gravity bottle is a bottle designed to hold a definite mass of distilled water at 4°C. For example, the specific gravity bottle may be designed to hold 25, 50, or 100 grams. Its volume, therefore, is 25, 50, or 100 cubic centimeters. One cubic centimeter of pure water weighs one gram at 4°C.

To use the specific gravity bottle, you follow these simple steps:

(1) Weigh the empty bottle.

(2) When the bottle is filled with the liquid (at 4°C.), weigh the bottle to determine the specific gravity.

(3) Subtract the weight of the empty bottle from the weight of the bottle filled with the liquid. This will give you the weight of the specific volume of liquid.

(4) The weight of the specific volume of the liquid is then divided by the weight of the same amount of water to determine its specific gravity. Thus, specific gravity equals weight of liquid/weight of water.

Most of the time you will use a hydrometer to determine specific gravity. The hydrometer consists of a float with a cylindrical stem and a bulb that is weighted at the bottom. The hydrometer is usually made of glass. The weight of the bottom of the hydrometer makes the hydrometer sink to a specific depth. The stem has a scale on its inside so that the readings can be taken at the surface of the liquid in which the hydrometer floats. (Readings must be taken across the top of the meniscus formed on the surface of the solution, as illustrated in figure 1-1.) Some hydrometers have a thermometer in the stem to indicate the temperature of the liquid at the time the reading is taken.

The common photographic hydrometer is used in the following manner:

(1) Put a sample of the solution to be tested in a 250-cubic-centimeter cylinder.

(2) Establish the temperature of the solution at 70° ± 1°F.

(3) Insert a hydrometer which has a suitable range in the solution.

(4) Allow the hydrometer to float free of the cylinder and to seek a stabilized position.

(5) Read the specific gravity across the meniscus formed by the surface of the liquid.

(6) Record the specific gravity reading and compare this reading to established standards.

When you are using a hydrometer, remember that it is a precision instrument and must be handled with care. You must also remember that accuracy of measurement is assured only when the hydrometer is absolutely clean, floating freely in the liquid, and when accurate temperature is maintained. An increase of only 5°F. will cause a decrease of 0.001 in specific gravity reading of the solution.

The problems which follow are examples of how specific gravity measurements are applied. They are typical and utilize the basic formula for determining specific gravity. The formula would appear as:

$$\text{Specific gravity} = \frac{\text{mass of a substance whose volume is known}}{\text{mass of an equal volume of water}}$$

or

$$\text{Sp. gr.} = \frac{W_e}{W_w}$$

where

W_e = weight of substance (or solution)

W_w = weight of water

Problem 1

Find the specific gravity (Sp. gr.) of concentrated sulphuric acid (H_2SO_4) at 20°C. (68°F.).

Formula:

$$\text{Sp. gr.} = \frac{W_e}{W_w}$$

Given:

1 ml of H_2SO_4 = 1.84 gm
1 ml of H_2O = 1.00

Solution:

$$\text{Sp. gr.} = \frac{1.84}{1.00} = 1.84$$

Problem 2

The specific gravity of a developing solution is 1.20. What is the weight of 125 ml?

Solution:

$$1.20 \times 125 = 150 \text{ gm}$$

The specific gravities of most substances may be obtained from tables found in the handbooks of chemistry.

Exercises (601):

1. An empty bottle weighs 65.3 gm. Filled the bottle with water that weighs 1151.1 gm, then fill the bottle with NaC1 (sodium chloride) solution, that weighs 120.7 gm. What is the specific gravity of the salt solution?

602. List the steps for obtaining specific gravity values, and state the standard temperature used to mix photographic solutions.

Obtaining Specific Gravity Values. From an earlier discussion, you probably recall that specific gravity is the ratio of the mass of a substance to the mass of an equal volume of water at the same temperature.

Standards of specific gravity for photographic solutions are generally determined by preparing standard mixes at 70°F. since most black and white solutions are used at that temperature. Variability of measurements is expected to fall with ±0.002 almost all or 99 percent of the time. In the text table below are listed some standards of typical processing solutions:

Solution	*Specific Gravity*
Primary developer	1.103
Secondary developer	1.102
Duplicating developer	1.065
Stop bath	1.048
Fixing bath	1.145
Stabilizer	1.002*
Antistatic solution	1.006

---

*Limit for the stabilizer is ±0.001; all other limits are ±0.003.

Procedure for obtaining specific gravity values includes the following steps:

(1) Fill the hydrometer cylinder with sample solution.

(2) Adjust temperature of the sample to read 70°F. ±1°.

(3) Dry the hydrometer thoroughly and carefully lower it into the sample, being sure that the stem of the hydrometer is dry, to within one-eight inch of the surface of the liquid.

(4) With they hydrometer cylinder on a level support, read the hydrometer at the top of the meniscus as seen along the side of the hydrometer stem. (Refer back to fig. 1-1.)

Compare the reading obtained against prescribed standards listed in the previous text table. Deviations beyond the limits call for a new sample and another reading. If the second reading is outside the limits, the validity of the mix is questionable. When the mix is certified by specific gravity measurement, record the reading on the mix sheet for future reference.

The purpose of chemical analysis of freshly prepared photographic solutions is to insure that all of the ingredients of a particular batch are accounted for by comparing the analysis with the makeup formula. Sometimes one or more of the ingredients in a developer solution is omitted or is weighed incorrectly. A complete chemical analysis of the solution will show discrepancies, if any exist, and corrective steps may be taken before a vital production run with photographic film is jeopardized. Ideally, when a chemical analysis is performed in certification of photographic developers, it should be correlated with an appropriate dip test, since the dip test shows the photographic effect produced by the chemicals in the solution.

Exercises (602):

1. The standards of specific gravity for photographic solutions are generally determined from mixes at what temperature?

2. List the steps in the procedure for obtaining specific gravity values.

1-2. Analytical Balance

Regardless of the balance that you use to weigh chemicals, there are certain precautions you should always observe. You will recognize some of these precautions since they were stressed in your resident training.

603. State procedures, purposes, or precautions associated with particular points in the weighing process using analytical balances.

Usage of an Analytical Balance. Because cleanliness and accuracy are essential in chemical weighing and mixing, some of the precautions will be stressed again. For example, in the matter of cleanliness, you should be careful not to spill chemicals when weighing them. Avoid spilling them on the balance or over the work area in order to prevent chemical corrosion on the balance and possible contamination of other chemicals in the work area. Furthermore, any chemical inadvertently spilled should be cleaned up immediately.

Because class S weights are commonly used to compound analytical reagents or standard mixes, avoid handling the small weights. Through corrosion, perspiration and oil on your hands can change the true weight of these small weights and thereby result in inaccurate chemical measurements. Such inaccuracy is caused by corrosion making the weights heavier than they should be. To prevent corrosion, handle the small weights with a pair of tweezers or foreceps with bone tips. You should acquire the technique of using the least number of weights possible when weighing chemicals. For example, it is preferable to use a single 3-gram weight rather than a 1-gram and a 2-gram weight. When counterbalancing a measure of chemical, try the larger weights first and then the smaller weights in systematic order.

In the work area, you should always cover the chemicals except the one that is being weighed. This precaution usually assures you that contamination of one chemical with another is prevented. Always weigh the chemicals in the order that they are listed in a given solution formula. By following the listed order, you are less likely to omit any of the chemical ingredients. In addition to weighing the chemicals in their listed order, watch their quantity, particularly when the quantity is greater than the maximum limit of the balance. You should never exceed the rated maximum limit of a balance as the overload can seriously damage the bearing of the beam. If weight is not too critical, you can use a balance such as the one illustrated in figure 1-2. This particular balance is accurate to 0.1 gram and will handle up to 2,000 grams. Use a "trip" or triple beam balance to measure any amount of chemical that is larger than 150 grams.

If possible, the analytical balance should be kept in a room that is separated from the processing laboratory. For most effective measurements, the balance should be used in an area where the temperature remains constant and out of direct sunlight and air currents. Make sure that the chemicals to be weighed are at room temperature. By observing this simple precaution, you will avoid weighing errors that result from air currents, caused by temperature differences. To assure accuracy, maintain the balance absolutely level and on a solid base that protects it from vibration.

While an analytical balance is not in use, take the following precautions to prevent damaging the agate knife edges and pans. Raise the beam and the pan supports. Nothing should be left on the pans. Make sure that the door of the case enclosing the balance is closed.

Before you weigh chemicals, raise the beam and arrest the pans. You should not place chemicals directly on the pans because corrosion can result. Use weighing bottles, watch glasses, or aluminum laboratory dishes. When you test for equilibrium, lower the beam and then release the pans. Because of the porosity of paper, it should not be used on the pans of an analytical balance. Before removing chemicals or weights from the pans, they must first be arrested and then the beam raised. Do not move the rider unless the pans are arrested. A word of caution when using aluminum dishes—do not weigh sodium hydroxide in these dishes. This is an extremely caustic chemical, and it should be measured in a weighing bottle to avoid skin injury.

To prevent the pans from oscillating, place the larger weights in the center of the pans. When placing the weights on the balance pan, use care to avoid dropping them. Always doublecheck the results of a weighing by adding the values represented by the empty compartments in the box of weights and then record immediately in your notebook.

Sensitivity. For accurate measurement it is desirable to construct a sensitivity chart. Sensitivity can be defined as the linear displacement of the pointer for a difference of one mg in the masses. The displacement is derived from the point where the needle comes to rest during an unloaded condition. Sensitivity graphs should be made at 10-gram intervals over the entire range capability of the balance.

Exercises (603):

1. Regardless of the balance you use, what precautions should you observe when weighing and mixing chemicals?

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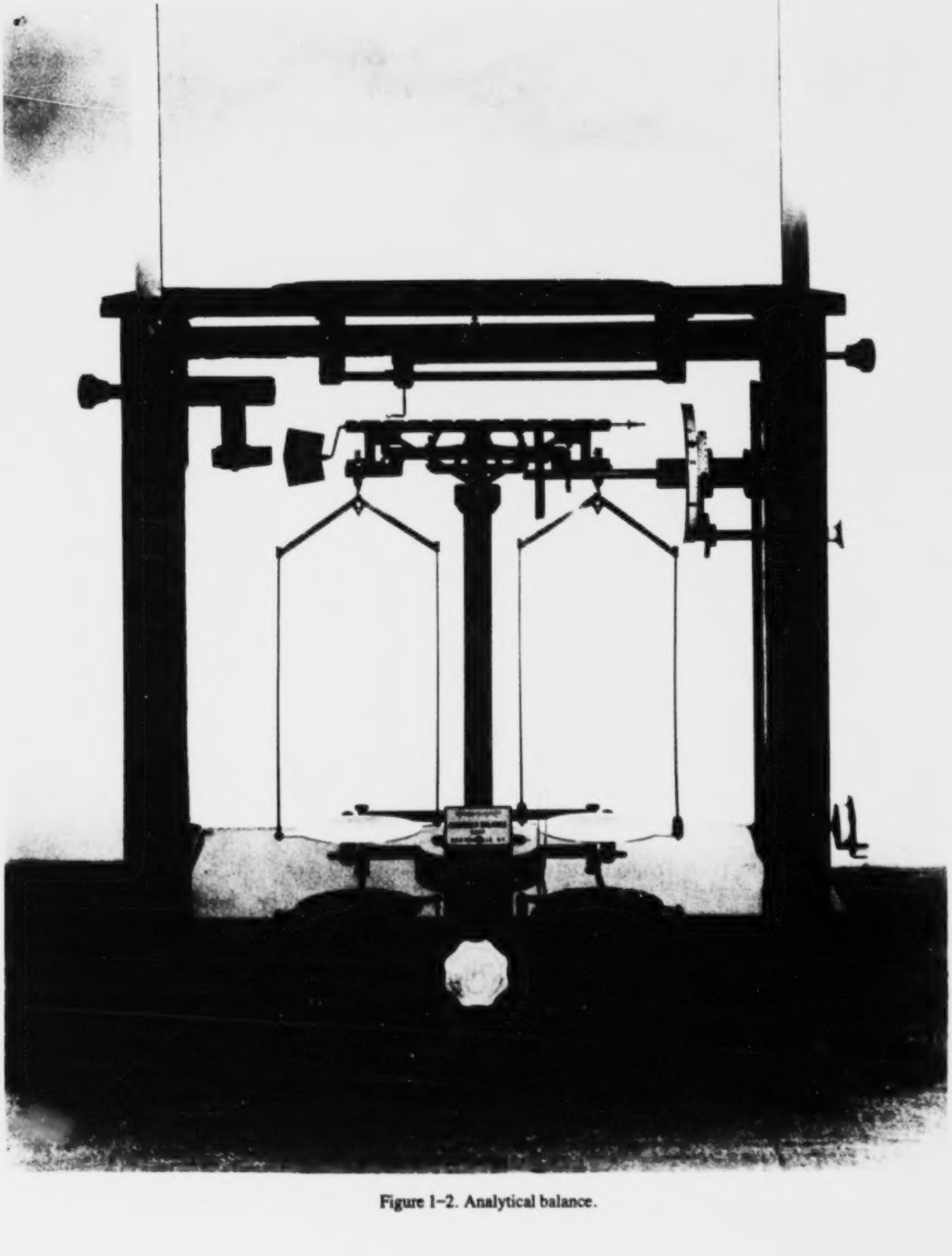

Figure 1-2. Analytical balance.

2. What is the reason for covering all other chemicals, except the one that is being weighed?

3. What is the reason of weighing chemicals in the order that they are listed?

4. To obtain the most effective measurements, where should you keep the analytical balance?

5. What precautions should you take when the analytical balance is not in use?

6. Why should you not place chemicals directly on the pans?

7. Why are aluminum pans discouraged when weighing a caustic chemical?

8. How can you prevent the pans from oscillating?

604. Given successive displacements of the pointer of a balance beam to each side, determine the rest point.

Calculating the Rest Point. The pivot points of a balance have practically no friction and, as a result, the balance beam will oscillate for quite some time, whether the pans are empty or full. Thus, it is desirable to save time and mathematically calculate a rest point for both unloaded and loaded conditions. To do this, observe an even number of successive displacements of the pointer to one side and and odd number to the other, average each one of the displacements separately, and then average the two averages to obtain the rest point. This accuracy should be sufficient for most work. A typical set of computations for a scale of 0–20 might be as follows:

Left	*Right*	*Average*	*Rest*
7.4			
7.2	12.2	7.23	
7.1	12.0	12.10	
3)21.70	2)24.20	2)19.33	
7.23	12.10	9.66	9.66

A typical set of computations for a scale graduated to the left (negative) and right (positive) of a zero point could be as follows:

Left	*Right*	*Average*	*Rest*
	+4.8		
−5.3	+4.6	−5.2	
−5.1	+4.4	+4.6	
2)−10.4	3)+13.8	2)−0.6	
−5.2	+4.6	−0.3	−0.3

Using the above calculations, the zero point is 0.3 of a scale division to the left of center.

Exercises (604):

1. You are calculating the zero point of a balance and come up with a set of computation as follows:

Left	*Right*
−6.2	+5.7
−6.0	+5.6
	+5.5

Determine the zero point to the right or left of center.

2. You have recently purchased an analytical balance with a scale of 0-20. You need to calculate the rest point and you come up with a set of computations as follows:

Left	*Right*
8.5	13.3
8.3	13.1
8.1	

Determine the rest point.

605. Indicate the proper methods for weighing chemicals on the beam-type analytical balance.

Methods of Weighing. A majority of the weighing done in a quality control operation is to measure a predetermined amount of a chemical such as 8.995 grams of silver nitrate crystals to make a 0.0500 N solution. The necessary weights are placed in the right pan. (Be sure that proper beam and pan arresting procedures are used.) The right pan is the heaviest and the scale pointer should be at its extreme left position. Chemicals are slowly added to the left pan until the pan lifts and the pointer swings. Find an approximate balance point by adding or subtracting small amounts of the chemical.

At this point you have an approximate balance. To obtain an accurate balance you must still add or subtract an extremely small amount of the chemical. However, you must first determine the rest point by using the same method employed in finding the zero point with empty pans. Also, you must find a sensibility value by noting the change in scale divisions when 1 milligram (0.001 gram) is added to one pan. The smallest weight that can be measured by a balance is called its sensitivity.

Exercises (605):

1. The principle in weighing is to place the object to be weighed on the ______________ pan of the balance and then add weights of known mass to the ______________ pan until weights and objects ______________ each other.
2. Where the pointer stops when there are no weights on the pans is called the ______________ point.
3. Where the pointer stops when there are weights on the pan is called the ______________ point.
4. The smallest weight that can be measured by a balance is called its ______________.
5. The number of scale divisions the zero point or rest point is changed when 1 milligram is added to one pan of the balance is its ______________.

606. Specify how to determine the amount of chemical to be added to or subtracted from a chemical mixture to obtain the proper measurement.

For an accurate measurement of the amount of chemical to be added or subtracted, make the following calculation:

$$\frac{\text{Rest Point} - \text{Zero Point}}{\text{Sensibility}} = \text{milligrams added or subtracted}$$

As an example, assume the zero point is 0.3, the rest point is +0.7, and the sensibility is 3. Place these values in the above equation and solve the problem as follows:

$$\frac{0.7 - (-0.3)}{3} = \frac{1.0}{3} = 0.33 \text{ milligrams}$$

A plus sign in the above calculation means that the left pan is heavier and 0.33 milligrams of the chemical must be removed. If silver nitrate is being weighed in the amount of 8.459 grams, the error correction is +0.00033 and the total amount of silver nitrate is 8.49533 grams. This still constitutes an error of 0.004 percent. If such an error is excessive, the removal of an additional 0.3 milligrams will improve accuracy.

Exercises (606):

1. *Situation*. After determining that the zero point for your analytical scale is −0.2, you now weigh out in the left pan 27.413 g of ammonium hexanitro to make a 0.500 $\underline{N}$ sulfate cerate solution. With the chemicals still in place, you determine the rest point for the balance to be 0.6. To obtain a sensibility value, you add 1-milligram weight (0.001 gram) to either pan and find the value to be two.

   What amount of sulfate cerate should you add or subtract to obtain an accurate amount?

Use formula:

$$\frac{\text{Rest Point} - \text{Zero Point}}{\text{Sensibility}} = \text{mg added or subtracted}$$

607. List the forces affecting weighing when using the analytical balance, and identify some of these forces with the conditions that bring them into play.

From the previous discussion, one can see that the analytical balance is quite accurate. However, this accuracy is based on the assumption that gravity is the only force acting on the material weighed and the standard weights. For extreme accuracy, other forces are considered. However, such accuracy is not normally required in the imagery production laboratory.

Buoyancy of Air. An object immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid. Since air is a fluid, the weight of a solid in air is less than its weight in a vacuum. The true weight can be determined by weighing the material in a vacuum, but this is impracticable. As a result, the body is weighed in air and a correction for the buoyant effect is applied. Another complication exists in that the standard weights are also subject to the buoyancy effect. No correction is necessary if the volume of the material being weighed is the same as the volume of the standard weight.

The vacuum weight of the material being weighed is its weight in air plus the weight of an equal volume of air. The mass of the air is the product of the volume and density of air and its ordinary density is about 0.0012 grams per centimeter to the third power (cm^3). The vacuum weight of the standard weights is also the weight in air plus the product of the volume and air density. The following formulas can be used to compute weight.

Let:

W = apparent weight of the object
W_o = true weight of the object
V = volume of the object
M_o = true weight of the standard weights
M = apparent weight of the standard weights
V^1 = volume of standard weights

then:

$$W_o = W + 0.0012V, \text{ or, } W = W_o - 0.0012V$$
$$\text{and}$$
$$M_o = M + 0.0012V^1, \text{ or, } M = M_o - 0.0012V^1$$

Since $W = M$ when the balance is in equilibrium:

$$W_o - 0.0012V = M_o - 0.0012V^1$$
$$\text{and}$$
$$W_o = M_o - 0.0012V^1 + 0.0012V$$

M_o is a known value (vacuum weight) and it is stamped on the standard weights. V and V^1 must be calculated. V^1 is determined by dividing the sum of the standard masses by their density. Small fractional weights may be disregarded. Most weights are made of brass whose average density is 8.4.

The volume, V, of the object is found in a number of ways: if the shape is regular, volume is calculated from the dimensions; if the shape is irregular and the density is known, volume can be found from the apparent weight in air.

Surface Moisture. Moisture is always present in the air, especially in a photographic laboratory where normal relative humidity is about 50 percent. Such moisture will often condense on objects being weighed. Fortunately, the brass weights collect little, if any, moisture. However, some objects being weighed may collect such moisture. Glass and porcelain are especially prone to do this. When appropriate, wipe (or blot) the object with soft cloth or absorbent paper. Do not use a wiping cloth (such as silk) that can cause static electricity.

Static Electricity. Porcelain or glass objects, when wiped, often collect an electrical charge. In this state, they can be attracted or repelled by other objects which could cause a change in apparent weight. If a liquid in a glass container is to be weighed, it may be necessary to remove moisture before using the container. Moisture on the inside may be removed by wiping the container, but such wiping could result in an electrical charge. In some cases, it is better to rinse the container with alcohol, repeat the process with ether, and then wait a short time for the ether to evaporate. The outside of the container may be dried by very gentle wiping. Objects which have been wiped should be allowed to stand for a few minutes so that the charge can dissipate—such a charge will dissipate more rapidly in an atmosphere of high humidity (say 50 percent). Low relative humidity contributes greatly to the formation of static electricity.

Exercises (607):

1. What complication arises when a solid is weighed in an air environment?

2. List the forces that can act on the material being weighed and the standard weights and thus affect precision.

3. What is the disadvantage of wiping porcelain or glass objects with silk?

4. What kind of an atmospheric condition contributes greatly to the formation of static electricity?

608. Cite the capabilities of the substitution-type balance.

Substitution-Type Balance. The previously discussed beam-type analytical balance is a rather delicate device and, in some cases, its use is somewhat difficult and time consuming. Analytical balances which are much simpler to use are now available. Typical of this relatively new equipment is a substitution-type balance which uses remotely controlled weights. These weights are selected in increments of 0.1 gram, 1 gram, or 10 grams. The precision reading dial registers in thousandths of a gram and the vernier scale incorporated in the balance is read to one ten-thousandth of a gram. Sample and weights are compared on a single beam arm. A representative balance of this type is accurate to ±0.05 milligrams and will weigh up to a maximum of 160 grams.

Exercises (608):

1. Cite the capabilities of the substitution-type balance.

1-3. pH Meters

One of the instruments used extensively in imagery production laboratories for process control and for certification of chemical solution is the pH meter. Since the activity of photographic solutions varies as their pH varies, measurement of that value gives a valuable check on the developing capability of a developer at any time during its life. For that reason, imagery production laboratories make frequent pH assessments during processing runs. In the chemical analysis section, pH meters are also used for potentiometric titrations of solutions.

In the following paragraphs you will find discussions on typical laboratory research and expanded scale pH meters currently being used in Air Force imagery installations.

609. Specify the general features of typical laboratory research pH meters and the expanded scale pH meters currently used in Air Force imagery installations.

The Laboratory pH Meter. This instrument (fig. 1-3) is a portable, battery-powered, precision pH meter having sufficient accuracy for most applications in imagery production laboratories. This particular model of pH meter operates within the pH range of 0 to 13 pH, and within the millivolt range of 0 to ±1,300 mv. It is a direct-reading, null-balance instrument that is readable to 0.01 pH units and 1 mv. This instrument has a relative accuracy of ±0.02 pH and a repeatability within ±0.01 pH. Manually, the temperature can be compensated between 10° and 40°C. Power for operating this pH meter is provided by internal batteries. The dimensions of this instrument are: height, 11 inches; width, 11½ inches; depth, 9 inches; weight, approximately 20 pounds. The instrument is encased in a wood-grained, acid- and alkali-resistant, plastic-covered hardwood box. This box has a hinged cover provided with a

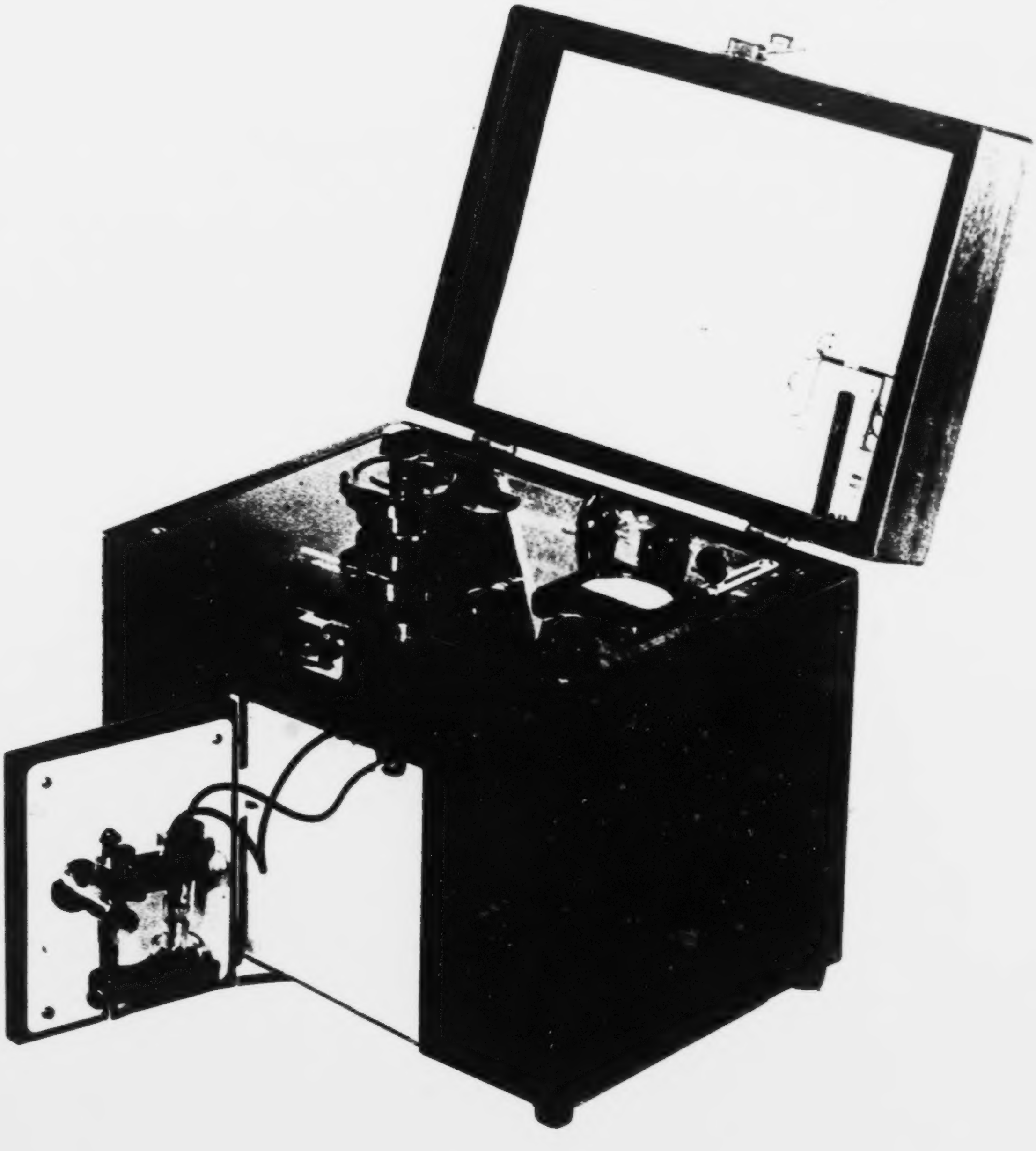

Figure 1-3. A laboratory pH meter.

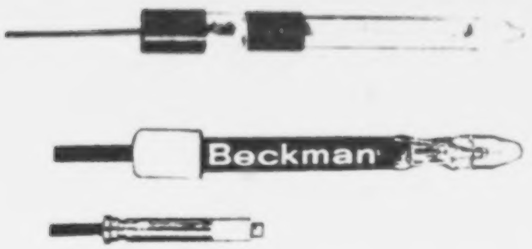

Figure 1-4. A pH meter electrodes.

carrying handle, snap and key lock, and a safety slide which automatically turns the instrument off as the cover closes.

The miniature electrodes, shown in the open door in figure 1-3, are standard equipment with this pH meter, but it can accommodate the large electrodes (fig. 1-4). The miniature electrodes are mounted inside the door of an electrostatically shielded compartment. The 5-inch electrodes require adapter plugs for connecting them to the instrument and a stand with clamps for external use.

The "Beckman" 71 pH Meter. Another instrument which is used in imagery production facilities is the Beckman 71 pH meter illustrated in figure 1-5. This meter has features somewhat different from those of the pH meter we discussed previously. These differences can be noted by comparison of the Beckman 71 pH meter specifications which follow.

DISPLAY
6-digit LCD plus status flags.
RANGE
pH 0 to pH 14; ±2000 mV; 0 to 100°C.
RESOLUTION
0.001 pH unit; 0.1 mV; 0.1°C.
RELATIVE pH ACCURACY
±0.001 pH.
mV ACCURACY
±0.1 mV or 0.1 percent of reading, whichever is greater.
TEMPERATURE ACCURACY
±0.3°C. maximum.
TEMPERATURE COMPENSATION
Manual or automatic; −1° to 101°C.
TEMPERATURE READOUT
0 to 100°C.
AUTO STANDARDIZE
pH 0 to pH 14; auto-find for pH 4, pH 7, and pH 10; auto-find accuracy is better than 0.01 pH unit.
AUTO SLOPE
Any pH.
AUTO READ
Flashes at ±1 mV over 8 seconds; locks at ±0.2 over 10 seconds.

Figure 1-5. Beckman 71 pH meter.

OPERATING TEMPERATURE RANGE
15 to 40°C. (ambient).
POWER
AC line, 120 (90 to 138) volts or 220 (165 to 250) volts; 50/60 Hertz.

This meter is a precision digital-display instrument designed for accurate measurements of pH and electrode potentials in a wide range of industrial and biomedical applications and in research. The digital display of the Beckman 71 pH meter reads to 0.001 pH and 0.1 mV. When the instrument is used with an ATC (Automatic Temperature Compensator) probe, digital display also reads temperature to 0.1°C.

This instrument offers, in compact size, simplicity of operation with maximum flexibility of use. Its advanced electronic design is combined with a simple diagnostic routine which allows easy user servicing, thus minimizing downtime and resultant costs.

Exercises (609):

1. What are the general features of the laboratory pH meter?

2. What is the normal pH and millivolt range of the model represented in figure 1-3?

3. What is the advantage of having a safety slide inside the hinged cover?

4. What are the general features of the "Beckman" 71 pH meter?

610. Given specific defects in a pH meter, state the probable cause and the precautions necessary to assure meter accuracy.

Operator Maintenance. All pH meters, like many of the units used in imagery production units, are carefully built and calibrated at the factory. The units shown in figures 1-3 and 1-5 are also aged at the factory and require careful handling in the laboratory. Avoid dropping or jarring these instruments since sharp blows may damage their meters and cause electronic failure. Cover the instrument with its plastic cover whenever it is not being used.

Like most instruments of this type, the outside of its case is finished with an acid and alkali coating. The face of the meter is protected by clear acrylic plastic which can be attacked by esters, ketones, glacial acetic acids, and chlorinated hydrocarbons. An antistatic solution is applied to the face of the meter to avoid erratic readings by the presence of the instrument operator. The face of the meter is cleaned with a soft cloth or disposable tissue. Actually, all that is needed is a very light dusting since hard rubbing may scratch or remove the antistatic solution coating. The instrument case and meter face should only be cleaned of dirt and stains with a mild detergent and damp cloth. Chemical solutions that may have inadvertently dripped on the instrument case should be wiped off immediately. Never use acetone or similar solvents to clean the instrument case or meter. You should be aware of the fact that chemical vapors may attack the exterior of the pH meter through any scratches or abrasions; therefore, handle the instrument carefully and keep it covered when it is not is use.

The input jacks, which emanate from the glass electrodes, must be kept clean in order that accurate pH measurements can be made. The accuracy of pH measurements depends upon maintaining a high input impedance to the instrument. Accuracy of pH measurements is also dependent upon proper grounding of the instrument. In new installations, most power outlets require that a three-prong plug be used, thus assuring that whatever instrument is being used will be properly grounded. In those installations with the older two-wire outlets, an adapter plug must be used. The adapter has a grounding lead which is firmly attached (by means of a plate-retaining screw) to the metal plate covering the outlet.

The cell chain consists of the glass and reference electrodes, the liquid junction reservoir, the liquid junction, and the electrode head with its internal contacts and cable connection. Any damage to these components or an interruption in the electrical continuity with the cell chain will not allow the instrument to operate properly.

Severe jolts (such as from dropping the pH meter) usually result in cracked glass electrodes. It is not apparent, but fine hairline cracks render the electrode partially or wholly inoperative. Quite often, the cracks are the results of scratching the electrode surface with a gritty substance. The only remedy for this fault is to replace the electrode.

Another form of electrode damage occurs as a defective reference electrode. This fault usually occurs when the inner electrode is contaminated by alcohol, acetone, or similar substance. Avoid lengthy immersions in such solutions and promptly rinse and renew the liquid junction immediately after each test; otherwise, you may contaminate the liquid junction reservoir. Again, the only possible remedy is the replacement of the reference electrode.

An "open" or electrically interrupted cell chain is usually the result of one of the following:

- Air bubble.
- Insufficient KC1 solution.
- Dry liquid junction.
- Faulty contacts.

The air bubble, referred to in the above list, may occur in either the glass or the reference electrode and the bubble blocks the lower part of either electrode. Once the liquid is shaken to dislodge the bubble, electrical continuity will be made. Insufficient KC1 solution in the liquid junction reservoir means that the lower end of the reference electrode is not covered, thus breaking continuity. The obvious remedy is to refill the reservoir with saturated KC1 solution, making sure that the solution level rises up to the filler hole.

The dry liquid junction is caused by storing the instrument over long periods of time with an empty KC1 reservoir. Dried solution sometimes plugs the capillary opening in the tip of the reservoir. Frequently, the plug can be removed by filling the reservoir completely and allowing the plug to dissolve. Quite often, pressure is needed to force the plug out; this may be provided by placing the ball of your thumb on the top of the reservoir and covering the filler hole on the side and pressing firmly on the solution. Pressure developed in this manner will force the KC1 solution through the capillary opening in the tip of the reservoir. Stubborn capillary opening plugs can be dissolved by immersing the liquid junction reservoir in warm distilled water for an hour or more and applying the thumb pressure again. After the plug is removed, take out the excess KC1 solution and restore the reservoir.

For precise measurements, it is best if you presoak the glass electrode in distilled water for 2 hours. After each test, you should carefully rinse and wipe the glass electrode. Do this conscientiously and you'll avoid erratic pH readings that are usually caused by allowing the glass electrode to dry with a film of foreign material on its surface. Any glass electrode left in this condition will show large potential changes and drifting pH readings when put back into use. The electrode may become so etched that it is entirely inoperative. In this case the entire glass electrode must be replaced.

A fresh liquid junction and clean electrodes are a "must" in order to obtain reliable and stable pH measurements. When using the reference electrodes, an automatic liquid junction renewal can be held by sliding the sleeve from the filler hole while a pH test is being conducted. Just before storing the instrument, fill the KC1 reservoir and replace the sleeve over the filler hole. You should also place the rubber cap over the liquid junction tip in order to prevent the drying out of the fiber and interrupting the liquid junction. The liquid junction tip should also be covered when the instrument is in storage or when it is not used over long periods of time.

Faulty contact in the electrode head may also cause an interruption in the continuity of the cell chain. Quite often, all that is necessary is to clean the metal tips and contact springs. To do this, you must first remove the cell chain from the support rod and unscrew the electrodes from the head. Next, wipe the metal tips and contact springs with a small ball of cotton or tissue that is slightly dampened with denatured alcohol. Be very careful and don't press too heavily on the contacts or allow the liquid to trickle into the head.

Like many fine, precision instruments, the pH meter (fig. 1-3) must be aligned to a standard reference (standardized) in order for you to obtain accurate measurements. This model of the pH meter must be standardized at least once each day, preferably at the beginning of each use period. The meter must also be standardized whenever it is disconnected from its alternating current power source. This particular pH meter is designed to be left connected to its power source at all times; however, when the instrument is not being used, its function switch must be set to the STANDBY (STBY) position. Whenever the glass electrode is subjected to a strong solvent or when either the glass or reference electrode is changed, the instrument must be standardized.

Exercises (610):

1. What is an important precaution to observe when handling the pH meter in the laboratory?

2. The accuracy of the pH measurements depends upon what two conditions concerning the electrical source?

3. What usually causes a defective reference electrode?

4. What usually causes an "open" or electrically interrupted cell chain?

5. What causes the dry liquid junction?

6. Before storing the instrument, what should you do with the reference electrode?

7. What adjustment is necessary before you can use the pH meter to obtain accurate measurements?

1-4. Distilling Apparatus

Distilled water should be used in the preparation and standardization of reagent solutions. Even this water as it comes from the tap may not be pure, but may be contaminated by dissolved gases such as carbon dioxide (CO_2) and the material dissolved from the container in which it has been stored. The dissolved gases may be removed by boiling the water for a short time.

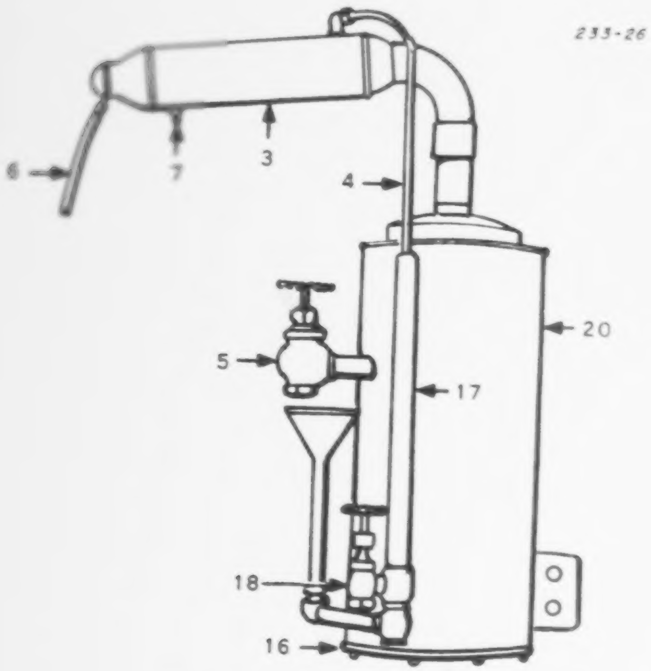

Figure 1-6. Consolidated electrically heated water still.

611. State the method for selecting distilling apparatus and the purposes of selected distilling apparatus components.

Distilling Apparatus. When selecting a water still, the imagery production facility should determine the capacity it will need. Laboratory stills range from 1/2 gallon to 10 or more gallons per hour. Select a distilling rate fast enough to allow for future requirements. The choice between electrically, steam, or gas heated stills usually depends on the facilities available at the imagery production laboratories. Electrically heated stills are generally preferred in most imagery production laboratories; they offer greatest convenience—easy installation, switch control, and no open flame. For economy, larger stills should be run off 230-volt lines. The basic startup and shutdown procedures are very simple; however, they must be accomplished in the correct order. To startup the still, you must first turn on the water, then turn on the power. To shutdown the still you simply reverse the order: first turn the power off, then turn off the water. The following operating instructions and figure 1-6 pertain to the still operating in the lab at the photo school.

Operating Instructions. Connection to water supply is made at the inlet (7). The water flows through the condenser (3) and the tube (4) into the water column (17) where volatile gasses are freed prior to entrance into boiler. The water enters the boiler where it is constantly maintained at the necessary operating level. Cooling water excess flows to the outlet (16) for connection to waste. Vapor from the boiling water rises into the condenser where it is condensed to pure water that discharges through the distillate delivery tube (6). The hard water bleeder valve (5) located at water level on the evaporator provides an adjustable outlet that continually bleeds boiling water waste to keep to a minimum the concentration of dissolved impurities. The amount of opening will vary with the hardness of the feedwater. IMPORTANT: Supply water must be turned on BEFORE heat is turned on. Heat must be turned off BEFORE supply water is shutoff.

The still is operating properly when a small amount of vapor is seen escaping at the vent at the end of the condenser. After the water in the evaporator begins to boil, this vapor should become visible. If not, reduce the amount of water entering at the inlet (7). A water control valve should be installed in the incoming water line at this point. If too much vapor is escaping, adjustment of the valve will reduce the amount. Once satisfactory setting is made, no further adjustment is required unless plant water pressure fluctuates.

The condenser assembly (3) is easily removed for access to the boiler (20) for cleaning. After each run of the still, the valve (18) should be opened and the boiler drained to remove sediment that may have accumulated. Over a period of time some scale will accumulate in the evaporator. The rapidity of concentration depends upon the hardness of the water. This scale can be removed from the boiler (or evaporator) walls with a blunt instrument. The fitting connecting valve (18) to the boiler should not be allowed to clog up. A highly desirable optional protective device is the automatic protective low-water cutoff. It automatically shuts off the electric current if the water level falls below proper operating level. It protects against damage if there is a water supply failure or if the still is accidentally operated dry.

Exercises (611):

1. What would be your considerations when you select a water still for your facility?

2. Give the purposes of the hard water bleeder valve and the automatic protective low-water cutoff.

1-5. Silver Recovery

612. State why silver recovery must be accomplished and when this task must be done.

Silver Recovery. Recovery of silver plays a big part in archival quality. There are, however, some additional factors to be considered in silver recovery, especially in laboratories that maintain a high production rate in film or paper processing. The recovery of silver from fixing baths has, essentially, a 3-part function. First, silver is a precious metal in relatively short supply, and requires conservation; secondly, silver recovery increases the efficiency of the fixing bath chemicals; and thirdly, silver recovery is often profitable.

Silver Recovery Potential. Before establishing a silver recovery program in the imagery production laboratory, it is desirable that some idea of the potential recoverable silver be predetermined. Essentially, you should know how much fixer is used in the laboratory. The solution records for any given processor within the laboratory indicate the volume of used fixer that must be handled for silver recovery. As an example, assume that your laboratory processes 1,000 feet of 9½-inch wide aerial film in a given time. If negative film is processed, the yield of silver is 5.5 to 8.00 Troy ounces of silver. Aerial duplicates for the same length of film would provide a yield of about 2.5 to 6.5 Troy ounces of silver. For the negative film then, you might receive from $3.25 to $8.45 for each one thousand feet of film processed. This estimate is based on a value of silver amounting to $1.30 per Troy ounce. However, the yield in silver would not be quite this profitable since rental or purchase of the equipment performing the silver recovery process subtracts from the silver recovery profit. Also, your laboratory may sell the unprocessed, but recoverable, silver to a commercial refiner. Since the refiner requires a profit and may possibly install the necessary recovery equipment, your actual profit will be somewhat less. Even if the entire silver recovery program is handled entirely by your laboratory, there are many costs other than equipment. Chemicals used, exposure-density, level of fixer buildup, efficiency of recovery system, electrical power consumed, salaries of personnel, etc., all must be considered as a reduction of any potential profit from silver recovery.

Chemical Savings. Under some operational conditions, lowering the silver concentration in a fixing bath by using an electrolysis method can lengthen the usefulness of the bath. There is a chemical saving since the fixing bath does not have to be dumped as soon, if the silver recovery was not performed. Such a chemical saving also contributes to lessened water pollution. Thus, fixing bath will be effective over a longer period of time. There are, however, other considerations since fixing baths are often diluted by water carried over during processing. In addition to dilution, other chemicals may be carried into the fixing bath and change its characteristics. Thus, even though there is a considerable decrease in silver content, the fixing bath is still being diluted and infused with other chemicals which shorten its life regardless of the silver content. In order to prolong the life of the fixing bath, the solution must be continually reconstituted by means of a replenishment program to replace the ingredients lost through deterioration or dilution. Of the various recovery methods, it should be noted that any chemical savings as a result of silver recovery can be accomplished only in the electrolytic method of recovery.

When an ammonium-type hypo fixing bath is used, the electrolysis method can increase the life up to 20 percent. However, this increase is obtained only under ideal low-dilution rates. Sodium-type hypo fixing baths are sensitive to silver buildup and, as a result, are more responsive to the removal of silver. If dilution is kept to a minimum with the sodium hypo fixing bath, it is possible to increase the life of the fixing bath from 40 to 50 percent. In actual practice, the increased life is considerably less.

If silver recovery is being accomplished and replenishment programs are being carried out, a consistent program of fixing bath quality control must be instituted to obtain maximum efficiency of the fixing bath and guard against any possibility of fixing film in a bath that can no longer efficiently carry out its purpose.

Recovery Methods. In general, there are three separate methods of recovering silver from the used fixing bath. These methods are metallic replacement, electrolytic, and chemical precipitation. Any one of the three methods can be used by itself; however, it is also possible to use the methods in combination. Each individual laboratory must choose the method most suited to its particular operation.

As previously mentioned, the electrolytic method of recovery is the only one that allows reuse of the fixing bath. Let us look at this system in more detail.

Electrolytic recovery. In this method, two electrodes (a cathode and an anode) are placed into a tank containing the silver-bearing hypo. In general, it is better to use a separate tank in which the spent hypo is collected rather than suspending the electrodes in the hypo tank of a machine. An electric current is passed between these electrodes causing the silver to plate out on the cathode. The amount of current must be carefully determined. If the current becomes too high for the amount of silver present, it will cause the formation of silver sulfide which stops the plating on the cathode and effectively destroys the fixing bath. However, excessively low current will not recover sufficient silver to make the process economically practical. If the current is too high, there is usually a warning that sulfiding of the bath is likely to occur. This warning consists of a somewhat brownish coating on the silver plating on the cathode rather than the usual cream colored coating. The maximum current used depends on whether sodium or ammonium hypo is used in the bath, on the acidity of the bath, and on the silver concentration and the sulfite concentration in the solution.

Some type of agitation or recirculation system is necessary to supply fresh silver-laden fixer solution to the cathode. You'll need a fresh supply because the silver in the bath is gradually plating out. This slowly decreases the amount of silver, and increases the current, which eventually causes sulfiding. Under ideal conditions, using a sodium hypo fixing bath, the life of the bath can be increased as much as 40 to 50 percent. However, in actual operating conditions, the increase of solution life is usually much lower. Film fixing baths can tolerate a silver content of silver grams per liter. If prints are being processed, the silver concentration in the fixing bath must be kept below 0.5 grams per liter if stable prints are desired.

Paper is not fixed in recycled fixing solutions because stains may occur. A fresh fixing bath should be used for paper, and the bath should not be shared with film since paper contributes to an excess of foreign matter. In organizations having high print production, silver is reclaimed and the fixer is discarded.

Chemical control of the solution is necessary to insure that the operation of the recovery unit is balanced to the processing load. Such a balance, of course, is accomplished through the use of a replenishment program. A constant flow replenishment system provides a certain amount of agitation at the silver recovery area. In general, however, it is desirable to provide more agitation of the fixing bath at the point of silver recovery. Additional agitation is desirable in order to shorten the silver recovery process. Such added agitation in the holding tank can be accomplished through the use of mechanical devices or a compressed air type of agitation where air bubbles are formed at the bottom of the tank and gradually progress upwards. Such agitation is a variation of the well known nitrogen burst agitation utilized in development procedures.

As an example of a low-agitation system, assume you are collecting used hypo in a tank equipped with an electrolytic unit. The capacity of this tank is about 50 to 60 gallons of solution which contains 19 ounces of silver. In such a case, the cathode would have an area of about 32 square feet. With only compressed air agitation, the unit would require about 20 hours of operation to remove 98 percent of the silver in the solution. The total capacity of this type of unit is approximately 600 Troy ounces. Thus, it could be used at this level of operation for about a month before desilvering is required. On the other hand, a high-agitation system could recover the same amount of silver with 1 square foot of cathode area. If the plating current were 15 amperes, the unit could recover approximately 1½ Troy ounces of silver per hour and would require a 12- to 13-hour operational schedule. Such a plate would have a capacity of approximately 80 Troy ounces of silver which could be collected in 4 days, at which point desilvering is required.

Metallic replacement. This method requires that used hypo solution be brought into contact with a metal surface. The metallic material used is often steel wool. The discarded hypo is collected in a tank, then flowed at the rate of 2 gallons per minute through two tanks in series. Each of these two tanks contains steel wool which should be suspended so that it will not touch the sides or bottom of the tank if the tank is of metal construction. Corrosion could result if the steel wool contacted the metal tank. Silver in the hypo solution collects on the steel wool. After the collection process is complete, the steel wool is removed from the tank and dried. A technique of this kind will remove from 60 to 99 percent of the silver—the actual amount is dependent upon the relationship of the flow rate of the used fixer and the volume of steel wool suspended in the tank.

Another method of metallic replacement consists of using zinc dust or scrap metal. This method is quite efficient, and it is possible that 3 Troy ounces of silver can be expected from each Troy ounce of scrap metal. One-half ounce of glacial acetic acid is added to the holding tank for each gallon of used fixing bath. As the solution in the tank is agitated, 2/3 ounce of zinc dust per gallon of used fixing bath is slowly added to the solution. Other metals, such as iron filings, granulated or sheet zinc, or scrap tin plate, can be used but the action will be much slower and less complete. The solution is now allowed to stand for about 24 hours. As a check on removal of silver, immerse a bright strip of copper in a sample of the solution for one minute. If the copper acquires a white, silvery luster which indicates that silver is still in the solution, add 1/4 ounce more of the powdered zinc per gallon of hypo solution. Once again, the mix is thoroughly stirred and allowed to sit overnight. At this point, test again by immersing another strip of copper. When all of the silver has precipitated, filter and dry the sludge. This sludge is the material that now contains the silver. Due to the change in chemistry caused by the immersion of the metallic material and the addition of glacity acetic acid, the fixing bath is not recommended for additional use.

Chemical precipitation. Used fixing baths that were desilvered by the chemical precipitation method must be discarded. The method requires the addition of certain compounds to the fixing bath in order to precipitate the silver. The used hypo is poured into a nonmetallic tank. One ounce of sodium hydroxide solution is added to each gallon of hypo. The sodium hydroxide solution is prepared by dissolving two pounds of sodium hydroxide in one gallon of cold water.

CAUTION: Add the sodium hydroxide very slowly to the surface of the water to avoid any spattering. Always use cold water when preparing the sodium hydroxide solution. The use of hot water could cause the solution to boil with almost explosive violence. Sodium hydroxide (lye) can cause serious burns.

The fixing bath must be thoroughly stirred while the sodium hydroxide solution is being added. After stirring is completed, the used fixing bath must be tested for alkalinity. This test should be accomplished by using "Eastman Kodak Testing Solution A" for print stop baths. Additional sodium hydroxide solution is added until the tests turns blue. This indicates that the solution is alkalized. At this point 1 additional ounce of sodium hydroxide solution for every 5 gallons of waste fixing bath must be added. Now, dissolve 2 pounds of sodium sulfide in 1 gallon of water. While stirring, add 1 ounce of the sulfide solution for each gallon of used fixing bath.

CAUTION: Keep the sulfide solution away from sensitized materials since the fumes will fog films and papers.

Let the mixture stand for about 30 minutes or until it is clear. Then check it by dipping out about 8 ounces of the clear solution and adding sodium sulfide. If the mixture clouds, the silver precipitation is incomplete. Add 1/4 ounce more of the sulfide solution for each gallon of used fixing bath. Again stir, let the mixture settle, and test again. Keep adding sulfide until all the silver is precipitated. Let the mixture settle for 8 to 12 hours and then drain off and discard the clear solution. Draw off the clear solution to a point just above the sludge at the bottom of the tank. Refill the tank with used fixing bath and repeat the recovery procedure. When the sludge reaches this 1-foot mark, transfer the sludge to a muslin filter cloth. Dry it by some appropriate means (such as exposing it to sunlight or drying it in an oven).

An alternate method of chemical precipitation requires the use of sodium hydrosulfite. You must have 1 ounce of sodium hydrosulfite and 1 ounce of desiccated sodium sulfite per gallon of exhausted fixing bath. Add these chemicals to the used fixing bath in a dry form then thoroughly mix the bath. Dissolve the chemicals in water and then pour them into the used fixing bath as you stir it. After about 8 to 12 hours, draw off the clear liquid, filter out the sludge, and dry it.

Exercises (612):

1. The recovery of silver from fixing baths has, essentially, a 3-part function. What are they?

2. Chemical savings as a result of silver recovery can be accomplished only in which method of recovery?

3. Explain the electrolytic recovery method.

4. When using the electrolytic recovery method the maximum current used depends upon what?

5. Explain the metallic replacement recovery method(s).

6. Why is the fixing bath not recommended for additional usage after performing the metallic replacement method?

7. Explain the chemical precipitation recovery method(s).

8. List two precautions when performing the chemical precipitation method.

9. When using the metallic replacement method, the actual amount of silver removed is dependent upon what two things.

Chemical Mixing and Certification of Solutions

DEPENDING UPON the kind of processing facility, chemical procedures will range from adding water to premixed and packaged processing solutions to the compounding of special formulas and conducting elaborate analyses on various processing solutions as they are being used.

In this chapter, we discuss the preparation of solution used in precision processing facilities and the accuracy and controlled conditions needed for certifying these solutions before their use in the laboratory. Because of the large volume of solutions which are used by the Air Force imagery production facilities, we also discuss the means for handling and storing these solutions to preserve their effectiveness. Let us begin our discussion by describing the kinds of chemicals required to mix the necessary photographic solutions.

2-1. Chemical Solution Processing

Processing solutions used in imagery production laboratories are prepared so that they do not adversely affect the quality of the product. That means that chemicals of excellent quality are mixed under carefully controlled conditions in environmentally controlled chem-mix rooms.

613. State the standards of chemical quality found in imagery production laboratories.

Standards of Chemical Quality. The American National Standards Institute (ANSI) publishes a series of standards covering all of the chemicals used in photographic processes. These ANSI standards contain specifications that establish the degree of purity and state limiting concentrations for potentially harmful impurities that may be present. Imagery production specialists can prevent faulty processing caused by the use of chemicals of inferior quality by using only a grade of chemicals that meets or exceeds these ANSI standards.

Chemicals such as sodium sulfite, sodium carbonate, hydroquinone, Metol, etc., that are used in large quantities by the photographic industry are designated as "Photo Grade" by most suppliers of chemicals. This designation means that the chemical so rated meets the ANSI specifications for photographic grade chemicals. "Photo Grade" or similar designation is not, however, one of the standard designations of chemical purity commonly used by chemical manufacturers. The quality designations used are given in the following paragraphs with a brief definition of each.

Primary standard. A special manufactured and tested analytical reagent of exceptional purity. Used exclusively for standardizing laboratory volumetric solutions and preparing reference standards.

ACS or reagent grade. A grade of chemical fully meeting the requirements of the American Chemical Society for reagent grade chemicals. Used in analytical laboratories for testing and evaluating other chemical preparations.

Chemically pure (CP). Chemically pure grade, generally exceeding U.S.P. or N.F. requirements, but of slightly lower quality than reagent grade.

National formulary (NF). A grade meeting the requirements of the most recent, or designated, issue of the National Formulary. U.S.P. and N.F. grade chemicals are primarily for drug use.

Purified. A grade for higher quality than *Technical*, often used where there are no official standards.

Technical. A grade suitable for general industrial use.

Generally speaking, ANSI photographic grade chemicals are within the quality range of U.S.P., N.F., and purified grades. C.P. grade chemicals are always suitable for photographic use, but are of a higher quality (and cost) than is generally required. Reagent grade and primary standard chemicals are very costly and are much purer than is required for photographic purposes. Some technical grade chemicals are satisfactory for photographic use. Their low price and availability make them desirable; but for imagery production applications, they should be thoroughly evaluated before use. Imagery production technicians using chemicals of unknown grade should obtain the ANSI specifications for the particular chemicals in question and perform the laboratory tests as given in these specifications. Chemicals failing to meet the given purity limits should not be used in preparing photographic solutions.

Exercises (613):

1. What agency establishes the standards of chemical quality?

2. What does the above agency publish that interests the imagery production technician?

3. What do these standards contain?

4. Chemicals that are used in large quantities by the photographic industry are designated as ________________ ________________.

5. List the standard designations of chemical purity commonly used by chemical manufacturers.

6. Generally speaking, ANSI photographic grade chemicals are found to be within what quality range.

7. You are preparing a photographic solution and are using a photographic chemical of unknown grade. What procedure should you follow?

614. State how the preparation of photographic solutions differs from ordinary chem-mix solutions.

Solution Preparation. The preparation of solutions for imagery production differs from ordinary chem-mix procedures only in the amount of care and cleanliness required. While ordinary photographic processes will permit quite large variations from the standard without significantly affecting the product, imagery production requirements are more critical and must be held to closer tolerances. Obviously, the product depends as much upon the quality of the chemistry as it does upon the control of any of its factors, and it is essential that rigid controls be maintained over the chem-mix function.

Exercises (614):

1. How does the preparation of imagery production solutions differ from ordinary chem-mix procedures?

615. State how to mix, store, and transfer processing solutions.

Mixing Chemicals. Depending upon the size of the photographic facility and the volume of work it handles, the chemical mixing section will range in size from a small efficient unit to a vast section employing a large staff and utilizing equipment capable of mixing huge quantities of chemicals into processing solutions. Except for the requirement of extreme cleanliness and accuracy of measurement, the function of small chem-mix rooms is routine and well known to imagery production technicians. However, operating a large plant which delivers processing solutions to the laboratories through systems of flowmeters and pipelines may present some problems.

In an imagery processing facility where the processing machines are located in several clean rooms, the chem-mix section is generally responsible for delivering the right solutions, in the correct quantities, to the proper machines at the right times. All this can be accomplished efficiently by routing the mixed and certified solutions through a system of flow raters (or flowmeters) and pipes to the processing machines. However, before this is done, the chem-mix crew must be informed as to the processor(s) being used, the solutions required, the replenishment rate to be established, the duration of the processing run, and the exact shutdown time. The crew normally receives written orders for the delivery of chemicals; however, the crew may be "intercom" system, or may be in direct voice communication with the processing personnel and the supervisor. When involved in imagery processing operations, variables are kept to a minimum; the operation is standardized and monitored, and control charts are maintained.

The main requirement of chemical mixing and storage equipment is that it must be resistant to chemical reaction. This limits the choice of structural materials to glass, certain plastics, hard rubber, and stainless steel. Stainless steel is used extensively because of its strength and durability, the ease with which it can be maintained, and its high resistance to chemical reaction. The stainless steel used in mixing and storage tanks for photographic chemicals should be type 302 or type 316. All seams should be welded and all welds should be polished and passivated to make them resistant to chemical reaction.

Since the requirements of individual laboratories will vary with the size of the installation and volume of work produced, it is not possible to prescribe a chemical mixing and storage setup that will satisfy all. Therefore, this equipment is made modular so that it can be assembled in an endless variety of combinations.

Mixing equipment. In chemical mixing, a wide variety of agitators are used. In combining liquids, it is only necessary to stir a liquid uniformly throughout the solution; vigorous agitation is not necessary. However, when dry chemicals are to be dissolved in a solution, the agitation must be sufficient to keep the chemicals in motion until each one is completely dissolved and to continue mixing until a uniform solution is obtained. Usually flat-bladed turbines or marine-type propellers are used. The propeller-type impellers may be installed in various off-center

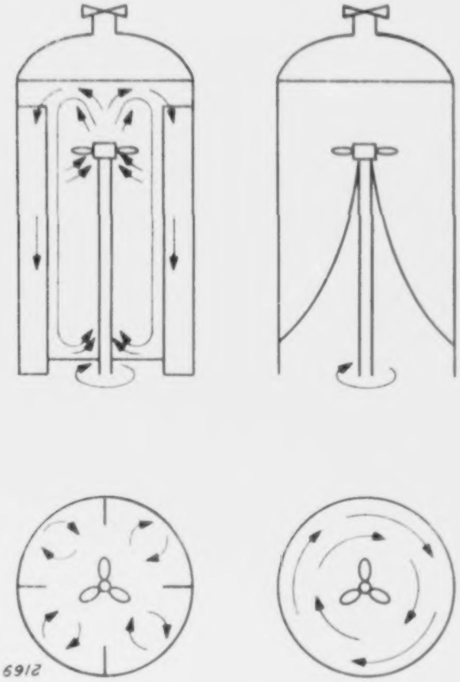

Figure 2-1. Flow patterns for on-center mixing.

positions, or on-center from the top of the tank. All systems have their advantages and the one selected should depend largely upon the characteristics of the chemicals being mixed. When preparing photographic solutions from dry chemicals, the main problem is the settling of chemicals in the bottom of the tank. This can be overcome by the use of an on-center, propeller-type agitator which produces a strong downward thrust to the bottom. However, this system produces a vortex in the solution which impairs mixing efficiency. Placing baffles in the tank will "spoil" the vortex and improve mixing efficiency. Figure 2-1 illustrates these actions.

Storage equipment. Because of the nature of photographic solutions, they must be stored under conditions of controlled temperature and in tanks which prevent unnecessary contact of the solutions with air. Moreover, they should only be stored in quantities to provide an adequate backup for the process so that they will be used before they deteriorate from age. Thus, the storage tanks are provided with lids, often with clamps to hold them in place, and are sometimes pressurized with nitrogen gas to exclude air. Storage tanks are available in sizes from 28 gallons to 1,000 gallons to enable a photographic chemical-mix facility to plan an efficient storage system.

Handling and storing certified solutions. Photographic chemicals are expended in two ways: by the actual production of the photographic image and by deterioration and waste through mishandling and aerial oxidation. The aim is, of course, to minimize the proportion that is wasted or allowed to deteriorate. Some general guidelines toward this goal include:

a. Use of mixing and storage facilities that isolate the solutions as much as possible from atmospheric oxygen. Storage and distribution systems incorporating an inert (nitrogen) atmosphere are preferable. Under these conditions, photographic solutions become, for all practical purposes, chemically stable. This, then, allows preparation and storage of larger, more economical batches.

b. Systems incorporating floating lids are not as desirable as nitrogen atmosphere systems, but are better than enclosed systems that include airspace. Minimizing oxidation in any system is achieved by having the exposed surface as small as possible in relation to the solution volume. For this reason, deep tanks are preferred over shallow tanks or trays. The preferred systems minimize the amount of pumping and transferring of solutions.

Maintenance. Stainless steel tanks should be cleaned frequently—at least once each week. It is generally sufficient to flush the tanks with clean, demineralized water and to rub out stubborn spots with a wet cloth. Never use steel wool or bronze scouring pads on stainless steel. Contact with dissimilar metals tends to induce corrosion. Avoid using any substance that will scratch or abrade the surface because chemicals may enter through fissures in the outer coating and cause internal corrosion.

Exercises (615):

1. How does the chem-mix section accomplish the delivery of the solution in correct quantities to the proper machine at the right time?
2. What information must be made available to the chem-mix crew before it can route the solution to the processing machines?
3. What is the main requirement of chemical mixing and storage equipment?
4. What are the choices of structural materials that are available for chemical mixing and storage equipment?
5. What structural material is used extensively in the imagery facility? Why?

6. When preparing photographic solutions from dry chemicals, the chemicals have a tendency to settle to the bottom of the tank. How can this situation be overcome?

7. What is usually provided with the storage tanks to minimize or exclude aerial oxidation?

8. In what two ways can photographic chemicals be expended?

9. What is essential in a system to minimize oxidation?

10. How do you maintain stainless steel tanks?

2-2. Certification of Solutions

Although there are several reasons for certifying photographic solutions, the principal one is to insure that they produce predictable and repeatable results. Depending upon the criticality of the mission, certifications may be limited or extensive. For example, some noncritical operations may require no more than the personal statement of the chem-mix technician that the solutions were properly prepared; some highly critical missions require complete sensitometric and chemical certification. In the following paragraphs, several procedures for certification of solutions will be given. It is up to the individual laboratory to decide which of these are applicable to their needs, or what modifications should be made in the event that none are completely applicable.

616. State the appropriate solution sampling technique used in the sampling process.

Sampling of Processing Solutions. Control of a photographic process requires that the chemical concentration of the solutions be maintained at standard chemical levels. Chemical analyses that indicate concentration are of value for control action only when the samples analyzed are representative of the processing solutions. A correct analysis of a nonrepresentative sample may do more harm than good in controlling the process.

Processing solutions may be turbid or contain floating particles, dispersed oil droplets, or a precipitate. Even a clear solution may have a concentration gradient between different parts of the processing machine tank. For instance, the chemical composition where the film enters is not the same as in other parts of the tank even though the solution is agitated or recirculated. For such cases a prescribed procedure must be used, with all samples being from the same location such as from a point near the tank overflow. These samples are representative of the solution at the prescribed sampling point, and successive analyses indicate variations in the concentration that is useful for control action.

Before sampling large batches of photographic solutions, allow sufficient time to pass so that chemicals have an opportunity to dissolve properly. Use the text table below for guidance as to time to wait before pulling a sample for chemical analysis.

Size of mixed batch	*Waiting time*
500 liters	30 minutes after topping
1500 liters	45 minutes after topping
2500 liters	60 minutes after topping with 1000 liters of water

Once you take a sample from the processing solution, a representative aliquot must be taken from the sample bottle for analysis. For a volumetric analysis, the aliquot is withdrawn 1 inch below the surface of the solution with a pipet. In general, no sample bottle should be shaken, and it should stand for 10 minutes after taking the sample from the processing solution. The wait lets large particles settle or lets turbidity (caused by aeration) to clear. However, any turbidity due to the presence of benzyl alcohol in the processing will not disappear. An alternative procedure for obtaining samples free from sediment is to centrifuge the samples before taking an aliquot.

Exercises (616):

1. When sampling a processing solution, what would you consider most essential for a correct analysis for control purposes?

2. What procedure would you follow to obtain samples free from sediment?

617. List the equipment necessary for a sensitometric certification of photographic solutions, and state how to perform a dip test and how to process the results of this test.

Sensitometric Certification. The first requirement of a developing solution is that it produces the photographic image wanted. A range of exposures must produce the expected contrast and density ranges within the established developing time and at the assigned temperature. This is determined for all developer-film combinations in your lab.

The equipment needed for sensitometric certification of photographic solutions is as follows:

- Dipstick (film strip holder).
- Dip tank or sensitometric processor.
- Sensitometer.
- Densitometer (preferably automatic recording).

The processing equipment should be constructed of stainless steel and should be provided with a unified operating agitation system. The agitation system may include gaseous turbulation (burst or continuous), oscillating vanes, or a combination of the two. The sensitometer should be intensity modulated; and where the workload warrants, an automatic recording densitometer is employed. In some imagery installations, the senistometric strips are exposed, read, and plotted by a separate sensitometric section. Regardless of who conducts the test, it must be done.

To perform a dip test, fill the stainless steel dip test tube with a sample of the newly mixed developer. Bring to 69°±1°F. in a constant temperature bath. Attach a properly exposed sensitometric strip to the stainless steel dipstick. (The film type will be selected in accordance with the developer, negative or positive, being tested.) Place the loaded dipstick into the cylinder and if there is no gaseous agitation, agitate vigorously upon immersion and then, once each minute thereafter until the prescribed time has elapsed. Then rinse, fix, wash, and dry. If your dip tank is provided with gas distributors, set the agitation cycle to agree with your requirements.

Measure all the densities and record the readings on the mix sheet for that particular batch. Compare results with the established standards. Deviations outside operating tolerances call for a retest. If the retest is beyond limits, conditions of exposure should be checked as well as the origin of the film stock used.

When the mix is certified, the sensitometric strip should be stapled to the mix sheet and filed for further reference.

The standards should be set to conform to the requirements of your mission. Some laboratories require only readings of the Dmin and Dmax, while others need a full sensitometric curve. When curves are plotted, you may use gamma as a reference standard, or you may select a desired Dmax—Dmin (ΔD) and plot an average gradient (G) and use it as a standard. In other situations, simply selecting three representative density steps as shown in table 2-1 gives satisfactory reference points. The method used should be the simplest one that will fulfill your requirements. However, the mission comes first, and if it is critical, simple tests may not be adequate.

Sensitometric processors are desirable when you have a large volume of critical materials to process. It is used not only to process dip tests for solution certification, but also to evaluate emulsion raw-stock and to establish process controls.

Exercises (617):

1. List the equipment needed for the sensitometric certification of photographic solutions.

2. What kind of agitation system should the processing equipment be provided with?

TABLE 2-1

DIP TEST STANDARD AND LIMITS

233-14

SOLUTION	EMUL.	DEV. TIME	CLEAR. TIME	WASH TIME	DENSITIES STEP	DENSITIES STANDARD
Primary (tank)	SO1188	9' 36"	5' 00"	5' 00"	6 8 9	0.14±.06 0.40±.12 0.80±.15
Primary (Repl.)	SO1188	9' 36"	5' 00"	5' 00"	6 8 9	0.16±.06 0.60±.12 1.05±.15
Secondary	SO1188	3' 00"	5' 00"	5' 00"	6 8 9	0.28±.08 1.15±.15 1.70±.15
Duplicating	SO1137 or SO1127	30"	5'00"	5' 00"	6 8 9	1.00±.10 1.61±.15 1.86±.15
1-D-80 70mm	SO1129 or SO1159	4' 00"	5' 00"	5' 00"	6 8 9	0.35±.05 1.20±.15 1.20±.15
2-D-80 70mm	SO1137 or SO5427	1' 20"	5' 00"	5' 00"	6 8 9	0.33±.08 0.90±.12 1.20±.15

3. To perform a dip test, what do you fill the stainless dip test tube with?

4. When comparing the results of the dip test with established standards, you find deviations outside the operating tolerance. What do you do?

618. Specify how chemical certification of a processing solution is done and how to certify the pH of solutions.

Chemical Certification. The chemical certification of processing solutions seldom requires a complete chemical analysis. Ordinarily, determining the pH, the total alkalinity, and specific gravity of the solution will suffice-particularly if these tests are accompanied by a valid sensitometric test.

Determination of the pH. The pH of a solution is the logarithm to the base of 10 of the reciprocal of the hydrogen ion concentration (H+), expressed in moles per liter, thus:

$$pH = \log_{10} (H+)$$

or

$$pH = \log_{10} \frac{1}{(H+)}$$

The hydrogen ion concentration of water solutions varies from 1 gram-ion for a strong acid solution to 1×10^{-14}, gram-ion per liter for a strong base. A neutral solution has a hydrogen ion concentration of 1×10^{-7}, or 1/0.0000001 grams/liter. The log 1/0.0000001 is −7, or $1/10^7$. The reciprocal of $1/10^7 = \frac{1}{1/10^7} = 7$.

Therefore, the pH of a neutral solution is 7. An easier way to calculate pH is to remember that 10^{-7} = (−7). Therefore, pH = − (−7), or 7. If the (H+) of a solution is 0.001, its pH is − (−3), or 3, and so forth.

Certifying the pH of solutions. The photographic effects of most processing solutions are dependent upon the effective concentrations of hydrogen and hydroxyl ions. The concentrations of these two ions are related so that only one of the two need to be determined. The electrical potential between the glass electrode of a pH meter and the solution surrounding it is indicative of the hydrogen ion concentration. In order to measure this potential with a pH meter, a constant potential reference (calomel) electrode is used to complete the circuit. The meter scale is calibrated in units of pH, which is defined as the negative logarithm of the effective hydrogen ion concentration.

Several factors which cannot be compensated, such as the presence of sodium ions and liquid junction potentials, lead to a bias in pH measurements. However, a true pH value is not necessary if the relative value obtained can be reproduced in the various laboratories within the allowable tolerance. To achieve this control, the meter, electrodes, buffers, temperatures, and technique must be kept within rigid standards.

The 95 percent confidence limits for individual pH measurements of developers whose pH was approximately 10.5, made over a period of several months by several analysts in different laboratories, were within a range of ±0.047 pH unit. The corresponding variability for developers whose pH was approximately 12 was ±0.060 pH unit. The variability is smaller for replicate analyses for one analyst using one set of equipment or for measurements over a shorter period of time.

The pH values of processing solutions and buffers and the responses of electrodes are dependent upon temperature. Therefore, to obtain reproduced pH values, it is necessary to standarize the temperature at which the measurements are made. Generally, pH measurements are made at the nominal temperature at which the photographic process is operated, unless otherwise specified. This temperature is usually 70°F., 75°F., or 80°F. A change of 10°F. produces a pH change of approximately 0.10 in a processing solution at a pH of 10.5, and a change of approximately 0.20 at a pH of 13.0. Thus, temperature control is more important at higher pH values.

Exercises (618):

1. When determining the chemical certification of a processing solution, what tests suffice if these tests are accompanied by a valid sensitometric test?

2. What are the photographic effects of most processing solutions dependent upon?

3. How do you measure the electrical potential between the glass electrode of a pH meter and the surrounding solution?

4. The pH values of processing solutions and buffers and the responses of electrodes are dependent upon what condition?

5. A change of 10°F. produces an approximate change of how many pH units in a processing solution at a pH of 10.5?

619. Specify the procedures used to store and condition electrodes.

In order to achieve temperature control, store all buffers, samples, and electrodes in a water bath within ±1°F. of the appropriate temperature. A constant temperature water supply is accomplished by using a thermostatic mixing valve unit. The bath should have a raised wire grid or other support for the beakers so that water circulating underneath will bring the solutions to equilibrium more rapidly. The water level should be approximately 1½ inches above the grid. Arrange the water input and overflow so that there is no appreciable temperature gradient in the bath. A thermometer mounted in the bath must be checked periodically.

A plastic bag should be placed around the connector at the end of the lead wire when the electrode is not in use to keep the tip of the connector and the metal ring clean and dry. If this area becomes contaminated, clean the connector with a lint-free cloth moistened with ethyl or isopropyl alcohol.

Any glass electrode gives erroneously low pH values of alkaline solutions containing sodium ions. Particular brands of glass electrodes may be used because of relatively low sodium ion error.

A dry glass electrode is equilibrated with an aqueous solution before it will function properly as an indicator for hydrogen ions. This phenomenon is assumed to be a hydration of the glass surface. The rate at which the glass surface becomes hydrated depends on the composition of the glass. Some glass electrodes are slow to reach this state of equilibrium. New electrodes should be soaked 4 hours in distilled water, immersed for 30 seconds in 3 $\underline{N}$ hydrochloric acid, rinsed off in distilled water, and then soaked for 12 to 16 hours in potassium borate buffer. If the electrode fails to give a satisfactory cross-check buffers after storage in the buffer for 16 hours, the electrode should be given the rejuvenation treatment for used electrodes.

To rejuvenate used electrodes, remove the electrode from the assembly, immerse it in a solution of 3 $\underline{N}$ hydrochloric acid for 30 seconds, rinse it immediately with running water, and soak it in potassium borate buffer for 16 hours. If the electrode still fails to produce satisfactory cross-check values, immerse the lower portion in 20 percent ammonium bifluoride solution (contained in a polyethylene container) for exactly 1 minute, rinse with distilled water, then immerse it for 30 seconds in 3 $\underline{N}$ hydrochloric acid, and again rinse with distilled water. If you must rejuvenate a glass electrode, use the recognized safety caution because ammonium bifluoride is very toxic. It is corrosive to the skin and glass. If this solution is spilled on the skin, immediately flush the area with water.

After such treatment, the electrode should be stored in potassium borate buffer for at least 16 hours before use. The solution of ammonium bifluoride can be stored in a polyethylene bottle and used again.

To store the electrode for an extended period out of the electrode assembly, fill it completely with saturated potassium chloride and replace the rubber caps.

Both glass and calomel electrodes contain mercury. Do not store with sensitized material. In case of breakage use special care to clean the area and to avoid contamination of photographic material or processing solutions.

Set up the electrode assemblies in units consisting of a calomel electrode and a glass electrode hold and guard. The fabricated electrode guard is shown in figure 2-2.

The electrode assembly is stored in the potassium borate buffer in the constant temperature bath for at least 1 hour before making measurements. This assembly should not be used for more than 8 hours in any 24-hour period. In control laboratories each shift should have a separate electrode assembly, clearly labeled. When not in use, the assembly should be stored in potassium borate buffer to restore the original sensitivity of the electrode.

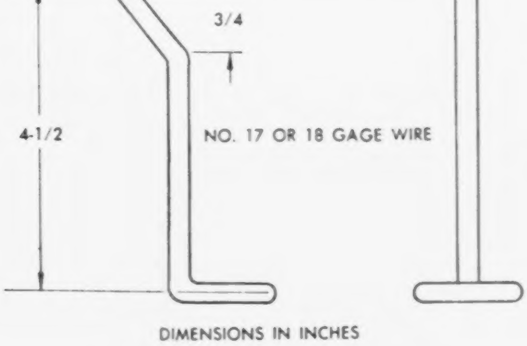

Figure 2-2. A guard for pH electrodes.

Exercises (619):

1. In order to achieve temperature control, how should the electrodes be stored?

2. What kind of an electrode will give you an erroneous low pH value with an alkaline solution containing sodium ions?

3. What must you do with a new, dry, glass electrode to make it reach a state of equilibrium with an aqueous solution?

4. How do you rejuvenate a used electrode?

5. How should the electrode assembly be stored when not in use?

620. State the basic procedure for calibrating the pH meter, the electrode assembly, and the procedures for the pH meter standardization and the electrode cross-check.

Calibration of the pH Meter. The pH meter and electrode assembly are calibrated by means of a primary standard buffer (potassium acid phthalate of borax) of known pH and cross-checked by a second buffer (borax or calcium chloride-calcium hydroxide) of known pH. Precautions should be taken to prevent buffer contamination. Covers should be kept over the buffers while in the constant temperature bath and removed only when the buffers are in use. Standardizing and cross-check buffers should be discarded and replaced every 4 hours during the working period, and the potassium borate storage buffer should be replaced every working day:

Potassium Acid Phthalate Buffer, 0.05 Molar

pH 4.00 at 70°F. (21°C.)
pH 4.00 at 75°F. (24°C.)
pH 4.01 at 80°F. (27°C.)

Borax Buffer, 0.01 Molar

pH 9.21 at 70°F. (21°C.)
pH 9.19 at 75°F. (24°C.)
pH 9.16 at 80°F. (27°C.)

Potassium Borate Buffer (used for electrode storage)

pH 10.5 at 70°F. (21°C.)
pH 10.4 at 75°F. (24°C.)
pH 10.4 at 80°F. (27°C.)

Calcium Chloride-Calcium Hydroxide Buffer (used for a cross-check buffer)

pH 11.98 at 70°F. (21°C.)
pH 11.88 at 75°F. (24°C.)
pH 11.79 at 80°F. (27°C.)

For the adjustment of temperature of buffers and sample, you must add approximately 100 ml of potassium acid phthalate buffer, borax buffer, calcium chloride-calcium hydroxide buffer, and the sample to a 150-ml beaker. Place the beaker in the water bath which is controlled to 70° ± 1°F., and allow the solutions to reach equilibrium.

Adjustment of a laboratory pH meter. The control panel of the typical pH meter found in the imagery production laboratory has a two-position operating switch in the upper right-hand corner. Just to the left of the switch is the temperature compensator control, this is set to the temperature of the sample solution. The range switch is located immediately to the left of the temperature control. The range switch is set to the pH mode of operation.

A milliammeter is located just under the operating switch and temperature controls. This meter needle is zeroed by the numbered control knobs below the milliammeter. Each time the temperature compensator is moved to a new value, the needle of the millimmeter must be zeroed.

Adjustment of the meter begins by placing the operating switch in position 1 and allowing the instrument to warm up for 10 minutes. Next, the temperature compensator is set to 21°C. (70°F.) and the range switch is moved to its pH position. The needle of the milliammeter is zeroed by adjusting control knob 1. After moving the operating lever to position 2, zero the meter needle by adjusting control knob 2. Wait 15 seconds to see whether the milliammeter needle drifts from zero. If the needle drifts after this waiting period, it must be looked at and checked by the maintenance unit.

Standardization of the pH meter. The first step in the standardization procedure requires you to lower the electrode assembly into a beaker containing the appropriate buffer while it remains in the water bath. Next, the pH scale is set to the recommended pH value shown in the table below:

Temperature	*Buffer*	*Dial Setting*
	(Samples below pH 7)	
70°F.	Potassium acid phthalate	4.00
75°F.		4.00
80°F.		4.01
	(Samples above pH 7)	
70°F.	Borax	9.21
75°F.		9.19
80°F.		9.16

After setting the pH scale of the meter, proceed through the following steps:

(1) Set the timer for 2 minutes.

(2) After 1½ minutes, adjust control knobs 1 and 2 alternately (refer back to meter adjustment procedure) until the needle of the milliammeter is zeroed for both positions of the operating switch lever.

(3) Lock down the pushbutton.

(4) At the end of the 2-minute period, adjust the needle to zero with the zero with the zero adjust knob (upper left-hand corner of the control panel) and then release the pushbutton.

(5) Raise and rinse the electrode assembly with distilled water.

Electrode cross-check. The procedure for cross-checking the electrodes of this model of a laboratory pH includes the following steps:

(1) Lower the electrode assembly into a beaker of the appropriate buffer, while it remains in a water bath, to obtain the cross-check values shown in the following table:

Buffer	*Control Limit*	*70°F.*	*75.°F.*	*80°F.*
Borax (for samples below pH 7)	Upper	9.26	9.24	9.21
$CaCl_2$-$Ca(OH)_2$ (for samples above pH 7)	Lower	9.16	9.14	9.11
	Upper	12.01	11.91	11.82
	Lower	11.95	11.85	11.76

(2) Set the timer for 1 minute.

(3) After 1/2 minute adjust knobs 1 and 2 alternately until the needle reads zero for both positions 1 and 2.

(4) Set the pH scale dial within 0.1 pH of the lower control limit.

(5) Lock down the pushbutton.

(6) At the end of 1 minute, adjust the needle to zero with the pH scale dial; then release the pushbutton.

(7) If the reading falls within the control limits found in the table above, continue with the procedures or report any sample results. If the reading does not fall within the control limits, replace the faulty electrode assembly and reject all results obtained since the preceding satisfactory cross-check. Repeat the standardization and electrode cross-check procedures with the new assembly.

(8) Raise and rinse the electrode assembly with distilled water.

Exercises (620):

1. How is the pH meter and electrode assembly calibrated?

2. What is the first step in the standardization procedures of the pH meter?

3. In the electrode cross-check, if the reading does not fall within the control limits, what procedure should you follow?

621. List the procedures for determining the pH value of a single sample, and state the appropriate course of action for conditions that may arise during the procedures.

Single Sample pH Determination. The procedure for determining the pH value of a single sample includes the following steps:

(1) Lower the electrode assembly into a beaker of sample while it remains in the water bath.

(2) Set the timer for 2 minutes and the pH scale dial at the approximate pH of the sample.

(3) After 1½ minutes, adjust knobs 1 and 2 alternately until the needle reads zero for both positions 1 and 2.

(4) Lock down the pushbutton.

(5) At the end of 2 minutes, adjust the needle to zero with the pH scale dial; then release the pushbutton and record the pH.

(6) Raise and rinse the electrode assembly with distilled water. If rinsing does not completely remove sample deposits, wipe the assembly with a cleansing tissue, and rerinse. Place it in the potassium borate buffer in the water bath or in the next sample to be tested.

Exercises (621):

1. List the procedures for determining the pH value of a single sample.

622. List the procedures for determining the pH values of multiple samples, and state the time limitation between standardization and the final cross-check.

Multiple Sample pH Determination. More often, the situation calls for determining the pH values of more than a single sample. In this case, the procedure is as follows:

(1) Repeat the steps above for each sample.

(2) Repeat the cross-check after the fourth sample measurement and place electrode in the potassium borate buffer, or in the appropriate standard buffer if more determinations are to be made.

Remember that no more than 15 minutes should elapse between any standardization and final cross-check.

Exercises (622):

1. List the procedures for determining the pH values of multiple samples.

2. Is there a time limit between any standardization and final cross-check?

623. List the procedures for determining the pH values of a successive group of samples, and state the procedure to follow if the pH is out of standard.

Successive Group pH Determination. When the volume of solution is such that more than one group of four samples can be analyzed for their pH values, the procedure includes the following steps:

(1) Repeat standardization of meter.

(2) Repeat cross-check.

(3) Repeat the steps above for each sample (no more than four).

(4) Repeat the cross-check after the fourth sample measurement and place electrodes in the potassium borate buffer in the water bath or in the appropriate standard buffer if more determinations are to be made.

Using the procedures for multiple samples, determine the pH for every batch of solution mixed and take the average value. Check this value against the standard pH for that solution; and if it is within tolerance, enter the value in the appropriate place in your certification sheet. If the pH is out of standard, it is cause for further investigation.

Exercises (623):

1. List the procedure for determining the pH values of a successive group of samples.

2. What happens if the pH is out of standard?

624. Define total alkalinity, and state the procedures for a total alkalinity test.

Total Alkalinity. While the pH measurement can give a quick evaluation of the alkalinity of a developer solution, it should be supplemented with a test for total alkalinity.

The total alkalinity (T. Alk.) of a processing solution is defined as the milliliters of 0.1000 N sulfuric acid required to titrate a specified volume of processing solution to pH 4.3. That pH was selected because most salts derived from weak acids show an inflection point in their titration curves near pH 4.3. E-O-X indicator is used since it has an abrupt color change near pH 4.3.

E-O-X indicator gives a sharper color change under fluorescent illumination, and therefore fluorescent is preferable to tungsten illumination. When titrating with acid under tungsten illumination, the color change is from green to light brown to purple. When titrating under fluorescent illumination, the color change is from green to gray to purple. In either case, the end point is the appearance of the first distinct purple.

Samples which are colorless, or nearly so, are titrated to a visual end point. Those which are highly colored and those in which it is desirable to see the entire titration curve are titrated potentiometrically. A pH meter is used with glass and calomel electrodes. The meter is standardized at the nominal temperature at which pH measurements are obtained.

A critical appraisal of the pH, specific gravity, and total alkalinity of a mix is useful in detecting incorrect amounts of the inorganic constituents and certain organic constituents.

The approximate total alkalinity of a fresh mix with a given formula may be calculated from the formula and the chemical equivalent weights of those constituents which react with acid or base. Experimentally, the amount of acid required to "neutralize" 1 gram of a chemical is not necessarily the amount needed to bring the pH to 4.3. However, for compounds in question, except for some borates and some phosphates, it is a close approximation.

Table 2-2 lists the various constituents and shows their chemical equivalent weights in those reactions whose end points occur nearest to pH 4.3. Using these chemical equivalent weights, it is possible to calculate the volume of 0.1000 N sulfuric acid required to bring any quantity of a constituent to its end point occurring nearest pH 4.3.

The numerical value for the total alkalinity of 1 liter of a processing solution is calculated by summing the amounts of acid which will bring each of the constituents, considering the concentrations used in the solution, to approximately pH 4.3. The sum of 1 liter of solution is then corrected for the sample size normally used in the analysis by using the following equation:

$$\text{The T. Alk. for a specific sample size} = \frac{(0.1000\ \text{N}\ H_2SO_4\ \text{for 1 liter})\ (\text{ml sample size})}{1000}$$

The sample size is so chosen that the total volume of sulfuric acid consumed falls between 25 and 45 ml. Bear in mind that sample sizes must be specified with all total alkalinity analyses. You may refer to table 2-3 for sample sizes.

The following are needed to conduct a typical total alkalinity analysis:

(1) Laboratory or expanded scale pH meter.
(2) General purpose glass electrode.
(3) Fiber-type calomel electrode (filled with saturated potassium chloride solution).
(4) Magnetic stirrer.
(5) E-O-X indicator.
(6) 0.1000 N sulfuric acid, H_2SO_4.
(7) Potassium acid phthalate buffer 0.05 molar.
(8) Borax buffer, 0.01 molar.

TABLE 2-2
ALKALINITY OF PROCESSING CHEMICALS

233-19

Constituent	Formula	Mole Wt.	Equiv Wt.	Alkalinity* Calculated**	Alkalinity* By Experiment
Borax, 5-Mole	$Na_2B_4O_7 . 5H_2O$	291	146	68	70
Elon	$HOC_6H_4NHCH_3 . 1/2\ H_2SO_4$	172	0	0	0
Hydroquinone	$C_6H_4(OH)_2$	110	0	0	0
Sodalk, 8-Mole	$Na_2B_2O_4 . 8H_2O$	276	138	72.5	72.5
Potassium Bromide	KBr	119	0	0	0
Potassium Iodide	KI	166	0	0	0
Sodium Bromide	NaBr	103	0	0	0
Sodium Carbonate (soda ash)	Na_2CO_3	106	53	189	---
Sodium Carbonate, monohydrate	$Na_2CO_3 . H_2O$	124	62	161.3	163.2
Sodium Hydroxide	NaOH	40	40	250	---
Sodium Sulfite	Na_2SO_3	126	126	79	76
Sodium Thiocyanate	NaCNS	81	0	0	5.3
Sulfuric Acid***	H_2SO_4	98	49	-360 per ml	---

*The ml of 0.1000 N sulfuric acid required to adjust 1.00 gram of constituent to pH 4.3

** $\frac{(1000)}{(\text{Eq. Wt})(\text{N Acid})} = \frac{(1000)}{(\text{Eq. Wt})(0.1000)} = \frac{(10000)}{(\text{Eq. Wt})}$ = ml of 0.1000 N sulfuric acid per per gram of constituent

*** This chemical makes a negative contribution to the T. Alk.; i.e., it has a pH less than 4.3)

TABLE 2-3
SAMPLE SIZES FOR TOTAL ALKALINITY

233-16

Processing Solution	Formula	Sample Size (ml)
Reversal Process First Developer	D-94	3.00
Replenisher	D-94R	3.00
Reversal Process Second Developer	D-95	4.00
Replenisher	D-95R	2.00
Reversal Process Clearing Bath	CB-2	2.00
Replenisher	CB-2R	2.00
Positive Developer	D-16	3.00
Replenisher	D-16R	3.00
Contrast Developer	D-19	2.00
Replenisher	D-19R	2.00
Negative Developer	D-76	3.00
Replenisher	D-76R	3.00
Negative Developer	DK-50	10.00
Replenisher	DK-50R	5.00
Negative Developer	DK-60a	5.00
Replenisher	DK-60aTR	5.00
Paper Developer	D-72	2.00
Recordak Developer	RD-1-16	10.00

The procedure to be used is visual titration with the following steps:

(1) Pipet the sample into a 120-ml Erlenmeyer flask (wipe the pipet before leveling). You may refer to table 2-3 for sample sizes.

(2) Adjust the final volume to read 50 ml by adding an appropriate amount of distilled water.

(3) Add 5 drops of E-O-X indicator.

(4) Titrate with 0.1000 N sulfuric acid from green to the first distinct purple. (If possible, use fluorescent illumination to view the end point.)

(5) Report the ml of titrant used in the previous step. (This is, by definition, the total alkalinity. Always indicate the sample size when reporting the results.)

An alternate procedure (visual titration) can be used, and it makes use of the following reagents:

- M.E.P. indicator
- Potassium acid phthalate buffer.
- Borax buffer.

NOTE: This indicator may be ordered through normal supply channels from Trutest Laboratories, 261, So 3rd Street, Philadelphia, PA 19106. Both the composition and the concentration of the indicator are unknown.

The steps in the alternate method of visual titration are:

(1) Place 1 milliliter of the sample developer in a 120-milliliter Erlenmeyer flask. To do this use a 1-ml pipet. Fill the pipet and, by using the forefinger on the top of the pipet, allow the sample to drain from the glass until the lower (center) meniscus of the fluid is level with the scribed line on the pipet. Using a piece of cleaning tissue, wipe the tip of the pipet, then allow the sample to drain into the flask. CAUTION: Do not blow through the pipet to empty it, as it is designed to deliver 1 milliliter by gravity.

(2) Add to the sample 10 drops of M.E.P. indicator from a dropping bottle or eye dropper.

(3) Fill a 50-ml buret with 0.1 N sulfuric acid. Before starting to add the acid to the sample make certain that the lower meniscus is at the zero level of the buret.

(4) The sample and indicator solution will be green in color at the beginning of this operation but, as it is titrated with the acid, it will gradually turn gray. With each addition the flask should be swirled. At some point, a drop of acid will produce a small, localized purple area in the sample solution. This indicates the sample is near the end point of neutralization and, from that point on, acid should be added very slowly.

(5) It should take only 1 drop to bring about a change in color to a distinct purple. Such an instantaneous change indicates the end point.

(6) The buret may be read to 0.05 milliliters and this value is taken at that point on the graduated scale of the lower (center) meniscus. Record this volume.

(7) As stated above, this value, by definition, is the total alkalinity of the developer sample.

The procedure for potentiometric titration with the laboratory pH meter incorporates the procedure for adjusting and standardizing the pH meter discussed in previous paragraphs. In general, the procedure for making measurements of solutions with pH values of less than seven begins with:

- Adjusting the temperature of the buffers and the sample.
- Adjusting the pH meter.
- Standardizing the pH meter with potassium and phthalate buffer.
- Cross-checking with the borax buffer.

Once the previous procedures are completed, titrate the sample and report the result as follows:

(1) Pipet (wipe the pipet before leveling) the sample into a 150-ml beaker containing 50 ml of distilled water. (Refer to table 2-3 for sample sizes.)

(2) Place the electrode assembly and stirrer in the solution. Turn on the stirrer and immerse the tip of the buret into the sample.

(3) Titrate to a pH of 4.3 with 0.1000 N sulfuric acid, zeroing the needle with the pH scale dial as the acid is slowly added. When the region of pH 5 is reached, add the titrant in 0.10-ml increments, zeroing the needle with the pH scale dial after each addition.

(4) Report the ml of acid required to reach a pH of 4.3. This is, by definition, the total alkalinity. Always indicate the sample size when reporting the results.

(5) Remove the sample and rinse the electrode assembly with distilled water. If rinsing does not completely remove sample deposits, wipe the assembly with a cleaning tissue, and rerinse. Replace in potassium acid phthalate buffer.

After completing the total alkalinity tests on each new developer batch, check your findings against the standard and record these values in the appropriate spaces on your certification sheet.

Exercises (624):

1. Define total alkalinity (T. Alk.) of a processing solution.

2. Why is a pH of 4.3 selected for this titration?

3. Why is the E–O–X indicator selected for this titration?

4. Why is fluorescent illumination preferred to tungsten illumination?

5. How are samples which are highly colored titrated?

6. What does a critical appraisal of pH, specific gravity, and total alkalinity of a developing solution help you to detect?

7. How would you titrate samples which are colorless or nearly so?

8. In the visual titration for total alkalinity, the amount of titrant needed to titrate the 0.1000 N sulfuric acid from green to the first distinct purple end point equals what?

9. After completing the total alkalinity tests on each new developed batch, what should you do with your findings?

625. State the effects of conditions or agents on a fixing bath and the factors to consider for the desired pH and the hardening results.

Fixing Bath pH. The time that will elapse before the fixing bath begins to deteriorate depends largely upon the pH of the fixing bath. In practice, the thiosulfate fixing bath with potassium alum as a hardening agent is normally used as a pH above 4 and below 6. However, when chrome alum is used as the hardening agent, the pH is usually held to a range of from about 3 to 4.

Potassium alum is normally used as the hardening agent in fixing baths. The hardening produced is dependent not only upon the concentration of the potassium alum, but also upon the pH of the solution. Starting at a pH value of about 3.5 and working upward, the hardening action increases. The hardening action reaches its peak at a pH value of about 5.0. Beyond this peak, the hardening action decreases very rapidly until it becomes almost negligible at a pH value of about 6.0. Little, if any, hardening action takes place when the solution becomes neutral or alkaline.

Many factors must be considered when you want to determine the correct pH of the fixing bath. If the pH is decreased to any extent beyond the optimum limit for ideal hardening, there is a great possibility of emulsion damage. In addition, the low pH makes the task of washing the fixing byproducts out of the emulsion more difficult. Yet, if the pH is too high, the emulsion is subject to damage and staining, and the hardening agent tends to sludge out of the fixing solution.

Carryover of developer into the fixing bath tends to increase the alkalinity of the fixing bath as it is being used; thus, there is a tendency for a rise in the pH. Normally, however, the fixing solution is buffered against this increase in pH by acetic acid, sodium bisulfite, and/or boric acid that is contained in the fixing bath formula.

Exercises (625):

1. What is the pH of a fixing bath with potassium alum added as a hardening agent?

2. When chrome alum is used as a hardening agent, what range would the pH hold?

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3. What factors must you consider when you want to determine the correct pH of a fixing bath?

4. The hardening produced in a fixing bath is dependent upon what two factors?

5. What happens to the hardening action at a pH of 6 or above?

626. Define total acidity, and state the basic process for determining the numerical value for total acidity of a fixing bath solution and the procedures related to the process.

Total Acidity. Many times you use an acidic processing solution, such as a fixing bath. To control its quality and performance, total acidity determinations, together with pH and specific gravity measurements, are essential.

The total acidity (T. Acid) of a processing solution is defined as the milliliters of 0.1000–N sodium hydroxide required to titrate a specified volume of processing solution to pH 8.7. That pH was selected primarily because acetic acid shows an inflection point in its titration curve near pH 8.7. In many cases, acetic acid makes the major contribution to the total acidity. Phenolphthalein is a suitable indicator for this titration because of its color change at this same pH. In seasoned tanks and in fixing baths containing potassium alum, the color change is often obscured or is too gradual of visual detection. In these cases, titrate the samples potentiometrically to pH 8.7 using a pH meter with glass and calomel electrodes. Standardize the instrument at the nominal temperature at which pH measurements are obtained.

You can calculate the approximate total acidity of a fresh mix. To do this, you must know the formula and the volume of 0.1000–N sodium hydroxide required to bring 1 gram of each of the constituents to pH 8.7. Since the sample size used in total acidity determinations is not 1 liter, correct the volume of 0.1000–N sodium hydroxide for the sample size. The total acidity for a specific sample size is equal to:

$$\frac{(\text{ml } 0.1000\text{–N NaOH required for 1 liter})\ (\text{ml sample size})}{1000}$$

Choose the sample size so that the total volume of sodium hydroxide consumed falls between 25 and 45 ml. You must specify the sample sizes with all total acidity analyses.

Table 2-4 shows the effect of each of the constituents of a fresh Kodak Fixing Bath F–25 tank mix on the total acidity of the solution. Note that the total acidity of this solution is mainly a measure of the acetic acid content and that the potassium alum contributes approximately 24 percent to the total acidity.

For total acidity determinations, use the following apparatus:

- Beckman (Model G or H) pH meter.
- Beckman general-purpose glass electrode, No. 1190–80.
- Beckman fiber-type calomel electrode, No. 1170 (filled with saturated potassium chloride solution).
- Magnetic stirrer (Will Corp., No. 25216) with glass or Teflon-coated stirring bar.

Be sure to have the following reagents handy before you start work:

- Phenolphthalein indicator.
- 0.1000–N sodium hydroxide, NaOH.
- Potassium acid phthalate buffer, 0.05 Molar.
- Borax buffer, 0.01 Molar.

For visual titration, follow method "a" below; for potentiometric titration, use method "b" below:

a. For visual titration:

(1) Pipet (wipe the pipet before leveling) the sample into a 125-ml Erlenmeyer flask as directed by the following table:

Processing solution	*Sample Size (ml)*
Kodak Stop Bath SB–1	10.0
Kodak Stop Bath SB–5	25.0

(2) Add 3 drops of phenolphthalein indicator.

(3) Titrate with 0.1000–N sodium hydroxide to the first faint pink color.

(4) Report the ml of titrant used in step (3). (This is, by definition, the total acidity. Always indicate the sample size when reporting the results.)

b. For potentiometric titration using the Beckman Model G pH meter:

(1) For the preparation of the meter, follow the method given for total alkalinity.

(2) Pipet (wipe the pipet before leveling) 10.0 ml of fixing bath into a 250-ml beaker. This sample size is suitable for Kodak Fixing Baths F–5, F–7, F–10, and F–25.

(3) Add 100 ml of distilled water from a graduated cylinder.

(4) Place the electrode assembly and stirrer in the solution. Turn on the stirrer and immerse the tip of the buret into the sample.

(5) Titrate to a pH of 8.7 with 0.1000–N sodium hydroxide. Zero the needle with the pH scale dial as the titrant is slowly added. When the region of pH 8 is reached, add the titrant in 0.10-ml increments. Zero the needle with the pH scale dial after each addition.

(6) Report the ml of 0.1000-N sodium hydroxide required to reach a pH of 8.7. This is, by definition, the total acidity. (Always indicate the sample size when reporting the results.)

(7) Remove the sample and rinse the electrode assembly with distilled water. If rinsing does not completely remove sample deposits, wipe the assembly with a cleansing tissue, and rerinse. Replace in potassium acid phthalate buffer.

Exercises (626):

1. How is the numerical value for total acidity of a fixing bath determined?

TABLE 2-4
CONTRIBUTION OF CONSTITUENTS OF FRESH KODAK BATH

233-19

Constituent	ml of 0.1000 N NaOH needed to adjust 1 g of Constituent to pH 8.7	Formula Value (1 Liter)	ml of 0.1000 N NaOH needed to titrate each constituent of a 10.0-ml sample to pH 8.7
Hypo (sodium thiosulfate pentahydrate)	0	300.0g	0
Sodium Sulfite*	-0.9	5.0g	----
Acetic Acid, glacial	172.2 per ml	10.0 ml	17.2
Boric Acid	44.6	5.0g	2.2
Potassium Alum	60.8	10.0g	6.1
Calculated T. Acid			25.5

*Sodium Sulfite makes a negative contribution to total acidity, i.e., in solution it has a pH higher than 8.7.

2. How is the total acidity of a fixing bath defined?

3. What is one indication that your fixing bath is losing its effectiveness?

4. In seasoned tanks and in fixing baths containing potassium alum, why is it necessary to titrate the samples potentiometrically?

5. The sample size is so chosen that it falls within what range?

627. Name the instrument used to quantitatively determine the amount of silver in a fixing bath, and state how the instrument works.

Argentometer. Another instrument used to test the potency of a fixing bath, particularly as it is being used, is the argentometer. The potency is found by quantitatively determining how much silver is in the fixing bath. Its use, therefore, is better adapted to the processing laboratory rather than the chemical mixing section. Nevertheless, you should know how the argentometer operates.

This instrument consists of a light source, a transparent cell to contain the sample to be tested, a photocell, and a microammeter scaled in grams-of-silver-per-liter. The arrangement of these components is shown schematically in figure 2-3. The components are contained in a metal inclosure that has a meter installed on the front panel, and aperture to accept the sample cell.

The solution to be tested is diluted with water, placed in the sample cell and inserted in the instrument. Then the power is switched on and the lamp is moved forward and back until the light passing through the sample produces a deflection of zero grams/liter of silver on the microammeter dial. The sample cell is then withdrawn from the instrument and precipitating solution is stirred into the test solution. The solution changes color after this treatment. Finally, the test solution is reinserted in the instrument and the light to the photocell is attenuated in proportion to the optical density of the discoloration of the sample. Because the silver content of the solution is proportional to the optical density of the discoloration, the needle deflection indicates the quantity of silver present in the sample. The meter dial is calibrated in terms of grams/liter of silver; the value can be read directly.

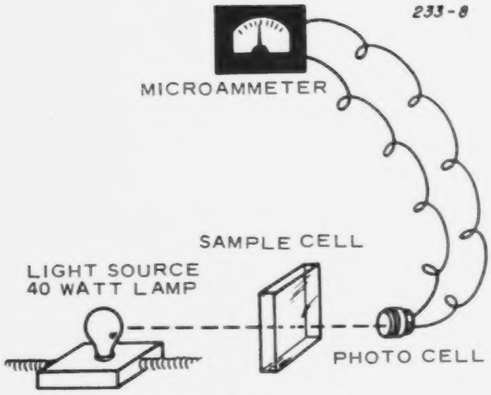
233-8
MICROAMMETER
SAMPLE CELL
LIGHT SOURCE
40 WATT LAMP
PHOTO CELL

Figure 2-3. Functional components of an argentometer.

Exercises (627):

1. What instrument can be used to quantitatively determine how much silver is in a fixing bath?

2. State the unique components of this instrument.

3. When the colored test solution is reinserted in the instrument, what happens to the light as it strikes the photocell?

CHAPTER 3

Analytical Solutions and Quantitative Determinations

UP TO THIS POINT in your study of imagery production, you have gained considerable technical knowledge, especially in the area of photographic chemistry. You can set up an operation involving a processing machine and be reasonably certain that the product (at least in the beginning) will be satisfactory.

Processing solutions do not last forever. Your machine or system developer (or other solution) capacity may be 10 gallons or 100 gallons, but eventually it becomes exhausted. At the moment that the first foot of film is processed, the solutions start to undergo a change. At first the change is hardly detectable, but it becomes greater as additional film is processed. Eventually the change reaches a point where it can be tolerated no longer—you have exceeded the established control limits of the operation.

At this point, the most obvious correction is to dump the solutions and refill with fresh solutions. Dumping, however, is an expensive correction. Also, consider the cycle: the process was standard in the beginning; it gradually approached and reached the control limit; you replaced the solutions. The process was once again standard, but again drifted toward the control limit. You can imagine the effect of this cyclic action on one particular density. (Also, note that processing was halted during the time the machine was drained and refilled.)

In order to extend the life of solutions and avoid needless expense, you perform chemical analyses. Other reasons for analyses are as follows:

- Assaying the quality of the chemicals used in the processing solutions.
- Certifying the accuracy of the mixes.
- Maintaining chemical control over the process.
- Establishing and maintaining a replenishment program.
- Determining if changes in the product are caused by changes in developer chemistry.
- Detecting and identifying contaminants in processing solutions.

You will learn how to prepare and use reagents and indicators, how to perform various chemical analysis procedures, and how to evaluate chemical procedures using statistical methods. Any chemical analysis must, of course, be supplemented by sensitometric tests. The chemical and photographic data is then correlated to determine the various parameters of processing. In the control of film processing, the preferred technique is to maintain chemical levels which are known to produce satisfactory photographic results. Such maintaining of solutions, in volume production, is usually done by replenishment.

3-1. Principles of Analysis

At this point you are acquainted with many facets of chemical analysis. You have studied such things as pH determination, specific gravity, and total alkalinity. These determinations are a part of analysis, but they do not tell the entire story. Generally speaking, these tests plus a dip test are conducted to certify a specific batch of mixed solution. You are thus reasonably assured that the developer or fixer will perform as forecasted. At times, however, it is desirable or even mandatory, to perform a detailed quantitative analysis. Such a detailed analysis will be done by using titration methods.

The principal reason for certifying photographic solutions is that you insure predictable and repeatable results. Depending on criticality of the mission, certifications may be limited or quite extensive. Some noncritical operations may require no more than a statement from the chem-mix technician that the solutions were properly prepared. Highly critical missions may require complete sensitometric and chemical certification, including a quantitative analysis.

628. Define accuracy as it relates to chemical analysis.

Accuracy. The procedures used in routine quantitative analyses have an accuracy deviation of about 2 percent or less. This inherent deviation is not photographically significant. However, you should have an understanding of what is meant by accuracy as it pertains to analysis.

The result of an analysis is accurate if it agrees with the known value. For example, if 2.50 grams per liter (grams/1) of Metol is found by analysis in a solution that was made up by dissolving 2.50 grams of Metol in a liter, the accuracy of the analysis is excellent. This is an accurate result and it is precise. However, a precise result is not necessarily accurate.

Exercises (628):

1. When can the results of an analysis be considered accurate?

629. Define precision as it relates to analysis; and, given various measurements, evaluate them for accuracy and precision.

Precision. Precision is the measure of a spread in the range of a number of results, usually expressed as the deviation from the mean or average value. As an example, consider a developer containing 5.00 grams per liter of hydroquinone with the following reported analysis results: 5.05, 5.01, 4.95, and 5.02. Both precision and accuracy are good. Now, consider the following results in the same developing agent: 4.00, 4.06, 3.98, and 4.05. These findings are precise but inaccurate since the hydroquinone concentration you found is about 20 percent lower than the true value.

To improve your accuracy and to gain confidence and experience, it is suggested that you mix a small, sample quantity of developer from bulk chemicals. Be sure that you use definite known amounts of each chemical. By making several analyses of your test developer you can perfect your technique, become familiar with the calculations for each chemical, and thus improve your accuracy. Do not expect an exact figure each time. Use fairly large amounts of solution in performing titrations. The smaller the quantity to be found, the greater the error, due to use of less titrant. For example, if 5 milliliters (ml) of titrant is used with an error of 0.1 ml in over or under titration or in reading the buret scale, the error is 2 percent. However, if 50 ml of titrant is used to find 10 times as much chemical, a 0.1-ml error amounts to only 0.2 percent.

In addition to the analysis of the unused test developer you mixed, you should partially exhaust the solution by developing fogged material. Analyze this used developer and see how your figures compare with the analysis of the unused developer. If you desire, you can also correlate these results with sensitometric data. Process a sensitometric strip in the fresh developer and one in the used developer. Read the densities and plot a characteristic curve for each strip. Try to explain the curve changes in terms of the chemical analysis.

Measurement accuracy in weighing chemicals or volumetric measurements is a critical factor in chemical analysis. Do the following exercises and then let us briefly review some of the things with which you should be concerned during measurement.

Exercises (629):

1. Define precision.

2. Situation: Four technicians titrated a solution containing a known developer that required a mean of 36.5 ml of titrant. The results of the analyses follow:

Technician	*Milliliters of Titrant*			
	1	2	3	4
A	35.75	36.74	37.75	38.00
B	35.45	35.50	35.50	35.55
C	36.40	36.45	36.55	36.60
D	35.45	36.25	36.75	37.50

Evaluate the precision and accuracy of the technician's results.

630. Specify the degree of accuracy required when weighing chemicals and the balance and weights required.

Weighing Chemicals. Accuracy of weighing chemicals must be carried out to the decimal place indicated by the preparation formula. Three decimal places means an accuracy to 1/1000 gram (0.001), two decimal places means accuracy to 1/100 gram (0.01), etc. This accuracy is obtained by the correct choice, use, and handling of the balance and weights. If the weight of a chemical is specified in grams to two or more digits to the right of the decimal point, use an analytical balance and class S weights. Do not use the analytical balance for weighing amounts of more than 150 grams.

Place the object to be weighed in the left-hand pan, weights in the right-hand pan—never drop either in the weighing pan. The pans should be supported by stop supports when changing weights or chemicals.

Never weigh chemicals by placing them on the pans—use weighing bottles, watch glasses, or aluminum dishes (do not use aluminum dishes for sodium hydoxide). Materials to be weighed should be at room temperature to avoid generation of air currents which lead to weighing errors.

A typical, but more sophisticated, analytical balance is the substitution-type balance using remotely controlled weights. Weights can be selected in increments of 0.1 gram, 1 gram, or 10 grams. The precision reading dial registers in the thousandths of a gram, and the vernier scale adjacent to the dial can be read to one ten-thousandth of a gram. Sample and weights are compared on a single beam arm. The balance is accurate to ±0.05 milligrams and will weigh a maximum of 160 grams. If weight is not too critical, you can use a balance such as the one illustrated in figure 1-2. This particular balance is accurate to 0.1 gram and will handle up to 2,000 grams.

Exercises (630):

1. To what accuracy is the weighing of chemicals carried out?

2. When should you use the analytical balance and class S weights?

631. Name the type of cleaning solutions best suited for cleaning glassware, and state the precaution to take when using cleaning solutions.

Cleaning Glassware. The standard unit of volume in the metric system is the liter. As a reference, remember that there are 3.785 liters in 1 US gallon. Most volumetric glassware are calibrated in liters or in milliliters (ml). It is desirable that your glassware be of a type certified by the manufacturer as to accuracy. Volumetric glassware must be kept scrupulously clean and free from grease. Three types of cleaning solutions are recommended:

a. Detergent is a "Nacconol" solution containing 50–100 grams per liter ("Nacconol" R.R. can be obtained from the National Aniline Company in Buffalo, N.Y. 14220). This is very effective material for most cleaning problems encountered. It is nontoxic and noncorrosive. Other detergents comparable to "Nacconol" may be used.

b. Sulfuric-dichromate is a "dichromate" solution, consisting of a solution of sodium or potassium dichromate ($Na_2Cr_2O_7$ or $K_2Cr_2O_7$) in concentrated sulfuric acid (H_2SO_4). The sodium salt is preferred because of its greater solubility. The cleaning solution is most effective against grease. It is also the most dangerous because of its strong acid, oxidizing, and dehydrating properties. The solution turns green as it loses its effectiveness and should be discarded.

c. Acid-alcohol is an "acid-alcohol" solution, consisting of one volume of 3 $\underline{N}$ hydrochloric acid (HCl) added to one volume of isopropyl or methyl alcohol. This is effective in removing dye stains and in cleaning spectrophotometer glass or quartz.

CAUTION: *Do not mix this solution in a closed container. The heat produced may cause a dangerous increase in pressure.*

These three solutions are used undiluted and may be reused until no longer effective. Do *not* draw any of these cleaning solutions into pipets or burets by mouth. Use a rubber bulb.

When mixing and handling the sulfuric-dichromate or acid-alcohol cleaning solutions, wear rubber gloves and goggles and observe the other safety precautions for handling concentrated acids. Never add water to sulfuric-dichromate solution in a container because excessive heat and steam are likely to spatter the hot acid. If acid is spilled on the skin or clothing or splashed into the eyes, flush the affected parts with a large amount of water. The water dilutes the acid and washes it away. Secure competent medical treatment immediately.

After treatment with a cleaning solution, the glassware should be thoroughly rinsed inside and out with distilled water. For reasons of economy, ordinary tap water may be used for the preliminary rinsing, reserving the distilled water for the final rinsing. If water droplets adhere to the inside walls of the glassware after 1 minute of draining, it is not sufficiently clean. Only an unbroken film of water should remain. Burets and pipets should drain in a vertical position. Volumetric flasks are inverted with the bottom at a slight angle from the horizontal so that drops on the bottom will drain away.

If volumetric vessels are clean, they generally do not have to be dried before being used with standard solutions. The slight amount of water which remains after rinsing and draining is removed by rinsing the vessel two or three times with small amounts of the solution to be used, allowing the vessel to drain completely between rinses. The solution should be well agitated in the vessel to insure that all the water is removed. If it is necessary to have the vessel dry, use a gentle stream of air.

CAUTION: *At no time should any piece of volumetric glassware be heated or rinsed with hot water. If heated above room temperature the equipment should no longer be regarded as within the specified tolerance because such heating may cause a permanent change in volume.*

Exercises (631):

1. What types of cleaning solutions are recommended for cleaning volumetric glassware?

2. What solution seems to be effective for most cleaning problems encountered in the photoprocessing laboratory?

3. What cleaning solution is most effective against grease?

4. What solution is most effective in removing dye stains and in cleaning spectrophotometer glass or quartz?

5. What precautions should you take when mixing and handling the sulfuric-dichromate or acid-alcohol cleaning solutions?

632. Specify the temperature that volumetric vessels are calibrated and the changes that occur in a solution when the temperature changes.

Temperature. The temperature at which volumetric vessels are calibrated is 20°C. (68°F.). For the greatest precision and accuracy, all measurements would be made at this temperature. Since this condition may not be practicable, it is important to consider the magnitude of the errors introduced into volumetric procedures by using standard solutions at temperatures other than 20°C.

Generally, glassware capacity changes with changes of temperature can be disregarded. However, do not confuse this with a change in volume of a solution with a temperature change—this change can be significant. Also, consider that a change in concentration of standard solutions will occur, with temperature changes. This may be of such a magnitude as to introduce appreciable errors. As the solution becomes warmer, its volume increases and the concentration of chemicals decreases.

Exercises (632):

1. For the greatest precision and accuracy, at what temperature should volumetric vessels be calibrated?

2. As a solution becomes warmer, what happens to its volume and concentration of chemicals?

633. For specified readings, name the appropriate part of the meniscus to use and tell how to determine the appropriate line of vision.

Meniscus. When liquid is contained in a narrow cylinder, the upper surface of the column of liquid takes on a curved shape due to capillary action. In the use of graduated cylinders, pipets, burets, and flasks, the lowest point of the meniscus should be taken as the reading. However, the determination of specific gravity is a special case in reading the meniscus. The top of the meniscus is read because the hydrometer is calibrated on that basis.

In observing the lowest point of the meniscus, it is very important that your line of vision be in the same horizontal plane as the bottom of the meniscus. This is easily ascertained if the graduations on the glassware extend at least halfway around the tube. The eye is correctly positioned when both front and back portions of the graduation coincide. You can see the meniscus more clearly if you hold a small white card with a rectangular black patch behind the meniscus. Raise or lower the card until the bottom of the meniscus is clearly outlined.

Exercises (633):

1. How do you read the meniscus when determining specific gravity?

2. In observing the lowest point of the meniscus, where should your line of vision be?

634. State how the quantitative determinations of the components of photographic solutions are performed.

Photographic Solutions. A solution is composed of a solvent and a solute. The solvents used most often in photography are water or alcohol. The solute is the substance dissolved in the solvent. For example, a developer is a solution where water is the solvent and the chemical components are the solutes. A dilute solution is one which contains a relatively small amount of solute in relation to the amount of solute which could be dissolved in the solvent at that temperature. A concentrated solution is one which contains a relatively large proportion of solute. A saturated solution is one which contains as much solute as it normally can dissolve at that temperature. Under some conditions it is possible to prepare a solution containing more solute in solution than a saturated solution. This is called a supersaturated solution and is prepared by producing a saturated solution at a high temperature and cooling it down without precipitating out or crystalizing the solute.

In order to conduct quantitative analysis, it is necessary to prepare solutions in specific strengths. These strengths are called percentage, molar, and normal.

Percentage. In many instances, you will need to find or use a percentage figure as an identifier of solution strength. One fairly common method you may be familiar with is the so-called criss-cross method of computing the dilution of a high-percentage solution to one of a lower percentage (fig. 3-1). Place the percentage strength of the strong solution at A. Place the percentage strength of the solution you dilute with at C. Our example uses water which is zero. Next, place the desired percentage strength at X, subtract X from A, and place the result at D. Now, subtract C from X and place the result at B. Finally, take B parts of A and mix them with the D parts of C, and you will get a solution of X percent.

An example of the above method is the preparation of a 28-percent acetic-acid solution from a 99-percent acetic-acid solution. To dilute the 99-percent solution to a 28-percent solution, take 28 parts of 99-percent solution and mix it with 71 parts of water.

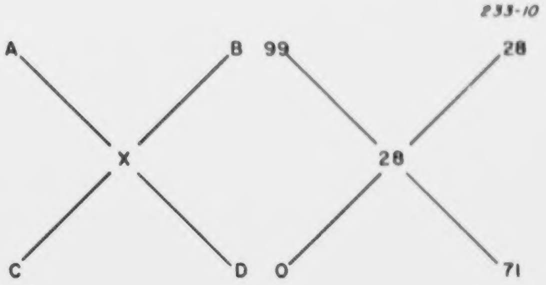

Figure 3-1. Computing dilution.

TABLE 3-1
ATOMIC WEIGHTS

SERIES	ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
1	HYDROGEN	H	1	1.0080
	HELIUM	He	2	4.003
2	LITHIUM	Li	3	6.940
	BERYLLIUM	Be	4	9.013
	BORON	B	5	10.82
	CARBON	C	6	12.011
	NITROGEN	N	7	14.008
	OXYGEN	O	8	16.000
	FLUORINE	F	9	19.000
	NEON	Ne	10	20.183
3	SODIUM	Na	11	22.991
	MAGNESIUM	Mg	12	24.32
	ALUMINUM	Al	13	26.98
	SILICON	Si	14	28.09
	PHOSPHORUS	P	15	30.975
	SULPHUR	S	16	32.066
	CHLORINE	Cl	17	35.457
	ARGON	Ar	18	39.944
4	POTASSIUM	K	19	39.100
	CALCIUM	Ca	20	40.08
	SCANDIUM	Sc	21	44.96
	TITANIUM	Ti	22	47.90
	VANADIUM	V	23	50.95
	CHROMIUM	Cr	24	52.01
	MANGANESE	Mn	25	54.94
	IRON	Fe	26	55.85
	COBALT	Co	27	58.94
	NICKEL	Ni	28	58.71
	COPPER	Cu	29	63.54
	ZINC	Zn	30	65.38
	GALLIUM	Ga	31	69.72
	GERMANIUM	Ge	32	72.60
	ARSENIC	As	33	74.91
	SELENIUM	Se	34	78.96
	BROMINE	Br	35	79.916
	KRYPTON	Kr	36	83.80
5	RUBIDIUM	Rb	37	85.48
	STRONTIUM	Sr	38	87.63
	YTTRIUM	Y	39	88.92
	ZIRCONIUM	Zr	40	91.22
	NIOBIUM	Nb	41	92.91
	MOLYBDENUM	Md	42	95.95
	TECHNETIUM	Tc	43	(97)
	RUTHENIUM	Ru	44	101.1
	RHODIUM	Rh	45	102.91
	PALLADIUM	Pd	46	106.4
	SILVER	Ag	47	107.880
	CADMIUM	Cd	48	112.41
	INDIUM	In	49	114.82
	TIN	Sn	50	118.70
	ANTIMONY	Sb	51	121.76
	TELLURIUM	Te	52	127.61
	IODINE	I	53	126.91
	XENON	Xe	54	131.30

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Another percentage expression of concentration is used in defining a specific number of grams of solute per 100 grams of solution. As an example, a 10-percent solution of sodium chloride is made by dissolving 10 grams of the salt in 90 grams of water. Note that both solute and solvent are measured in grams.

Molecular weight. Since we desire to make quantitative determinations of the components of photographic solutions, we are concerned with the weights of the components. Also, since our concern is with molecules of substances, it follows that we must deal with the molecular weights of substance.

The molecular weight of a substance is the sum of the weights of the various elements (table 3-1) contained in the substance. As an example, the molecular weight of sulfuric acid (H_2SO_4) is as follows:

Element	*Atomic Weight*	*Atoms*
Hydrogen (H)	1.008	× 2 = 2.016
Sulfur (S)	32.066	× 1 = 32.066
Oxygen (O)	16.000	× 4 = 64.000
	Molecular Weight	= 98.082

Another variation of molecular weight is called formula weight. This is defined as that weight in grams which corresponds to the formula of a substance as it is usually written. For example, the molecular weight of calcium sulfate ($CaSO_4$) is 136.146. The formula weight is 136.146 grams and is usually the same as gram-molecular (sometimes gram-mole or mole) weight. However, this designation also applies not only to compounds, but to elements as well. For example, a mole of nitrogen gas (N_2) is 28.016 grams of the element.

An additional measure of weight is the gram-atomic weight or gram-atom. This is the atomic weight of an element expressed in grams, such as 14.008 grams of nitrogen. The gram-atom and the mole are identical only when a molecule of an element consists of just one atom. The term gram-ion is the formula weight, or atomic weight, of an ion (an atom with a loss or gain of electrons) expressed in grams.

Molar solutions. Continuing our study of solutions, we see the term "molar solution" and normal solution. Both of these present a more reliable expression of solution concentration than those previously explained. The molar (or formal) solution is one which contains 1 gram-molecular weight or 1 gram-formula weight of a substance dissolved in 1 liter of solution. We find this method of expression particularly convenient because, first, all chemical reactions take place according to a fixed ratio of the gram-molecular weights of the reactants, and second, the volumes of solutions are easily measured.

A 1-molar (shown 1–M) solution contains 1 gram-molecular weight (1 gm mole) of a solute dissolved in 1 liter of solution. To illustrate, let us calculate the amount (by weight) of KCl needed to make a 1–M solution. First, we determine the atomic weight of K to be 39.10 and the atomic weight of Cl to be 35.46. The gram-molecular weight of KCl, then, is the sum of the atomic weights expressed in grams; thus 39.10 + 35.46 = 74.56 grams.

This quantity of KC1 is dissolved in a quantity of distilled water, and sufficient distilled water is added to bring the total volume of the solution to 1 liter. A 0.1–M would be made in the same way by using one-tenth of the quantity of 74.56 grams of KC1. A 2–M solution would be made with twice the gram-molecular weight, and so forth.

Some chemists use the term "formal" in connection with ionic substances. A substance in solution may be in several ionic forms. For instance, a 0.1 formal solution of sulfate ions may be composed partly of bisulfate ions and even partly of sulfuric acid, but the solution is still considered to be 0.1 formal with respect to the sulfate. The term "molar" describes either ionic or molecular substances.

Another example of a differentiating term is the use of molal (expressed as m.). Molal refers to concentrations of ions being added to a solution, only those which remain sulfate would be expressed as the molality of sulfate ions.

Normal solutions. Another method of expressing the concentration of solutions, based on the equivalent weight of the solute, is termed normality. A 1-normal (written 1–N) solution contains 1 gram equivalent weight of a solute in 1 liter of solution. In some instances, the molecular weight and the equivalent weight of a substance are the same. In such cases, the molarity and the normality will be the same. Equivalent weight actually has three definitions as follows:

(1) The equivalent of an acid is the weight of the acid which contains 1 gram of hydrogen ion (replaceable hydrogen) or the molecular weight divided by the number of the replaceable hydrogen atoms (ions) per molecule.

(2) The equivalent of a base is the weight which contains 17.008 grams of hydroxyl ions (replaceable OH), or the molecular weight divided by the number of hydroxyl radicals (ions) per molecule.

(3) The equivalent of a salt is that weight which contains one equivalent of its acidic or basic portion, or the molecular weight of the salt divided by the valence characteristic of the metallic or acidic group.

Following are examples of the above definitions:

Solute Compound	*Available H or OH Ions*	*Molecular Weight*		*Equivalent Weight*
HC1	1	36.5	$\frac{36.5}{1}$	= 36.5 gm
H_2SO_4	2	98	$\frac{98}{2}$	= 49 gm
Na(OH)	1	40	$\frac{40}{1}$	= 40 gm

In the above examples, the number of H or OH ions is readily seen by a casual examination. This is not always the case, however. For example, in acetic acid, whose formula can be written CH_3 COOH, there is only one available hydrogen ion rather than the three.

The equivalent weight of a substance, like the atomic weight or molecular weight, is simply a number which has no actual weight. But the gram-equivalent weight states a definite number of grams. Other expressions of equivalent weight are expressed as follows:

- Milliequivalent weight is the equivalent weight divided by 1,000.
- Gram-equivalent weight is the equivalent weight expressed in grams.
- Gram milliequivalent weight is the milliequivalent weight expressed in grams.

The application of equivalent weight to the kind of problems we meet in chemical analysis can best be shown by typical examples. For instance, determine the weight of iodine needed to make a 0.2–N solution by the following steps:

(1) Find the equivalent weight of iodine. (One atomic weight of iodine is equivalent to 1 atomic weight of hydrogen in forming HI, hydrogen iodide. Therefore, the atomic weight of iodine equals its equivalent weight.) Thus:

$$\text{Iodine} = 126.92 \text{ g eq wt}$$

(2) Find 0.2 of the gram equivalent weight:

$$126.92 \times 0.2 = 25.384 \text{ gm of iodine is needed}$$

(3) Dissolve 25.384 gm of iodine in water to make 1 liter.

If we wish to find the weight of sodium sulfate (Na_2SO_4) needed to make 500 ml of a 0.5–N solution, we do the following:

(1) Find the equivalent weight of sodium sulfate. The formula indicates that Na_2SO_4 contains 2 sodium ions, each being equivalent to 1 hydrogen atom. Therefore, the formula weight is twice the equivalent weight, shown as:

$$\text{Formula weight} = \frac{142.06}{2} = 71.03 \text{ eg wt}$$

(2) Find 0.5 of the equivalent weight:

$$71.03 \text{ gm} \times 0.5 = 35.515$$

The amount of Na_2SO_4 required for 1 liter of a 0.5–N solution is 35.515 gm.

(3) Find the weight needed for 500 ml:

$$35.515 \text{ gm} \times 0.5 = 17.7575 \text{ gm}$$

Thus, 500 ml of a 0.5-N solution contains 17.7575 gm of Na_2SO_4.

To prepare 500 ml of 0.2 N sulfuric acid from concentrated (98 percent) sulfuric acid, H_2SO_4 specific gravity = 1.84, we follow these steps:

(1) Find the equivalent weight of H_2SO_4. Since each molecular weight contains 2 hydrogen atoms, the equivalent weight is the molecular weight divided by two. Thus,

$$\frac{98.076}{2} = 49.04$$

the equivalent weight of sulfuric acid

(2) Find the weight of sulfuric acid needed for 500 ml of a 0.2–N solution. This would be the same as the amount required for 1 liter of a 0.1–N solution. Therefore,

$49.04 \times 0.1 = 4.904$ gm = the gram equivalent weight needed for 1 liter of 0.1 N, or 500 ml of 0.2–N, or 100 ml of 1.0 N

(3) Transpose weight to volume. If the acid were 100 percent pure, it would occupy

$$\frac{4.904}{1.84} = 2.67 \text{ ml},$$

where 1.84 is the specific gravity of the acid

(4) Find the volume of 98 percent sulfuric acid required. Thus,

$\frac{2.67}{0.98} = 2.72$ ml = the volume required to produce 500 ml of 0.2-N H_2SO_4

There are a number of reasons for conducting a chemical analysis. The primary reasons are probably the establishment and the maintenance of a replenishment program. The first step is to prepare various analytical solutions. Work the following exercises and then see how this preparation is done.

Exercises (634):

1. A developer is a photographic solution where water is a ______________ and the chemical components are the ______________.

2. In order to conduct quantitative analysis, it is necessary to prepare solutions of specific strengths. What are these strengths?

3. What method is available to you to compute the dilution of a high percentage solution to one of lower percentage?

4. The solvent used most often in photography is ______________ or ______________.

5. To prepare a 10 percent solution of potassium bromide, you would dissolve 10 grams of salt in ______________ grams of water.

6. What is the molecular weight of a substance?

7. What two methods present a more reliable expression of solution concentration?

8. What does a 1-molar (1–M) solution contain?

9. A method of expressing the concentration of solution based on equivalent weight of the solute is called what?

10. What are the three definitions of equivalent weight?

11. Determine the weight of iodine needed to make a 0.5–N solution. The equivalent weight of iodine is 126.9.

635. State the basic process for finding the concentration of chemicals in a sample, and list some of the more common color change indicators.

In order to conduct a quantitative analysis of the chemicals contained in a photographic solution, you first need to prepare various solutions. You take a representative sample of the solution being analyzed. You add a measured amount of standardized reagent to this sample. The concentration of the chemical (developing agent, restrainer, accelerator, etc.) in the sample is found by adding a measured amount of a specific reagent until the equivalence point is found by one of two basic methods: use an indicator which changes color abruptly at the end point, or use a specially designed potentiometer which measures the electrical potential (voltage) across two electrodes in the solution.

You add a specific reagent to the sample, drop-by-drop, until the end point is reached. The addition of the reagent in measured amounts is called titration. Using titration, the components of a compound can be isolated and measured. This is a method of volumetric determination of the strength of an acid, a base, an oxidizing agent, or a reducing agent. One method of finding the end point is by titrating a reagent until a color change is noted. Let us examine some typical color change indicators.

Indicators (Color Change). Indicators produce a color change indicative of an end point. For a rough determination of the acidity or alkalinity of a solution, you use litmus paper. This is a soft, white, unsized paper which

TABLE 3-2
TYPICAL pH INDICATORS

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pH INDICATORS		
pH	1 2 3 4 5 6 7 8 9 10 11 12 13 14	Preparation
Metanil Yellow	– R–T---------------Yellow----------------	.01% in water
Methyl Violet	– Y, G, B, –T -------- Violet------------------	.01%–.05% in water
Methyl Orange	– Pink, Red –T -----------Orange---------------	.01% in water
M.E.P. (E.O.X)	– Green -- T ------------ Violet ---------------	ready to use
Bromcresol Green	---Green -----T --------Yellow ---------------	ready to use
Alizarin	--- Yellow --Ⓣ -------- Red ------T – Purple---	.01% in water
Litmus	-------- Red----- T ---------Blue ------------	in paper form
Phenolphthalein	---------- Colorless ------- T-----Red ----------	.05 g in 50cc alchol – 50cc water
Alizarin	----Yellow -----T ------ Red --------Ⓣ Purple ---	.01% in water
Clayton Yellow	--------------- Yellow -------------- T – Amber.	.01% in water

NOTE: "T" is the Transition or Endpoint

has been soaked in an infusion of litmus and water and dried. Litmus becomes red at pH 4.5, and blue at pH 8.3. Thus, blue litmus paper changes to red in an acid solution, and red litmus paper changes to blue in an alkaline solution. Litmus paper tells you whether a solution is more acid than pH 4.5 or more alkaline than ph 8.3, but it does not respond at pHs between those limits. Moreover, it cannot indicate degrees of acidity or alkalinity in the ranges where it does respond.

There are other indicators that react at different points on the pH scale, as indicated in table 3-2. These are titrated into a sample of a solution being tested until a reaction (end point) involving a color change is obtained. There are indicators, called Hydrion papers, which are impregnated with combinations of indicators and which react at several pH levels. You use them just as you would use litmus papers. However, these papers render a variety of shades of color which correspond to the entire range of pH values. To measure pH using these papers, place a drop of the solution being tested on a piece of the paper and compare the resulting color with the color chart provided with the papers. Hydrion papers are quite adequate for laboratories which do not have chemistry laboratories, or whose work is not very critical.

A typical method of analysis by titration which involves a color change is the addition of an appropriate indicator to the sample being tested. The titrant (a known solution) is then added to the sample. This known solution is introduced into the sample by means of a buret. The end point is seen as a color change in the sample produced by the indicator when the desired reaction between the sample and the titrant occurs.

As an example of a color change, consider the calculation of the amount of bromide in a developer. This particular method shows a definite and easily recognized color change. The required reagents and chemicals are:

- Concentrated nitric acid.
- Metanil yellow, 0.2-percent solution.
- Silver nitrate solution (14.27 gm/1).
- Potassium bromide, 1-percent solution.

The following procedure is used:

(1) Place a 100-ml sample in a 300-ml flask.

(2) Add 100 ml of distilled water.

(3) Add 15 ml of concentrated nitric acid which is enough to neutralize the developer and furnish an approximate 10 ml excess.

(4) Add 4 ml of a 0.2-solution of metanil yellow. The color of the sample should be red.

(5) Add 10 ml of a solution containing 10 grams/1 of potassium bromide.

(6) Titrate the treated sample in the flask with a solution containing 14.27 grams/1 of silver nitrate. As soon as a portion of the silver nitrate solution is added, the sample turns blue.

(7) Continue titrating until the end point is reached. The color change is from blue-black to the original red, and the silver bromide precipitate will coagulate.

To calculate: if 28.50 ml of silver nitrate solution is required to react with the 100-ml sample containing 10 ml of standard potassium bromide solution, then

$$\frac{28.50\ (\text{ml AgNO}_3) - 10.00\ (\text{ml KBr})}{10}$$

$$= \frac{18.50}{10}(\text{AgNO}_3) = 1.85\ \text{grams/1 of KBr}$$

The indicator used in the procedure was metanil yellow. As you progress, you will find that there are many more available indicators. Some of the more common ones are Ferrion, indigo carmine, methyl orange, phenolphtalein, potassium chromate, and starch. Indicator solutions are prepared in advance to a specific formula. Such a preparation must be correct if the color change is to occur at the proper point. These solutions are mixed with the same exacting care used in preparation of reagents. Indicator preparation is simpler only because the number of components is fewer than in reagents.

Starch is a common indicator. This indicator in a 5-ml quantity is used, for example, in the determination of total sulfite, bisulfite, and thiosulfate in a fixing bath. The color indication is a change from blue to colorless. The starch indicator is prepared as follows:

(1) Add cold distilled water to 10 g of soluble reagent starch to make a thin paste.

(2) Slowly, while stirring, add the paste to 1 liter of rapidly boiling distilled water.

(3) Add 0.001 g of mercuric iodide (HgI_2) per liter as a preservative.

Exercises (635):

1. State the basic process for finding the concentration of the chemical in a sample.

2. List some of the more common indicators.

636. Indicate why potentiometric titration may be necessary.

Indicators (Electrical). A color change indicator cannot be used for every titration. For some solutions there may not be a suitable indicator. Other solutions may be so highly colored that a color change cannot be seen. Therefore, potentiometric titration is used. In this method two electrodes, one an indicating electrode and the other a reference electrode, are placed in the sample. These electrodes are such that the drop in potential between them is a function of one or more of the ions present in the solution. As the titrant is added, the rate of change of potential is maximum when the end point is reached. The equipment used for measuring a change of potential is a pH meter such as the Beckman, Model G, or a similar meter. Some laboratories may use other devices such as the automatic titrator. This instrument automatically plots titration curves on special graph paper as it simultaneously adds the standardized reagent solutions to the samples chosen for analysis. In the absence of an automatic titrator you must manually record titration readings and plot the results to produce a titration curve. In this text we will consider manual recording of titration information.

A pH meter has two electrodes. The indicating electrode for acid-base titrations is a glass electrode because its potential is a function of the silver ion concentration in the solution. The reference electrode remains at a constant potential during the course of the titration. A calomel reference electrode filled with potassium nitrate is used for titration of halides with silver nitrate-potassium chloride, if used, would plug the electrode with precipitated chloride.

The potential across the electrodes is measured and recorded manually when a pH meter or potentiometer is used. Potential measurements can be read on a pH scale rather than on a scale calibrated in volts since the scales are proportional. If the instrument has been standardized against buffers of known pH, the readings are true pH. Most titrations, however, do not require such standardization.

At first thought, it seems that certain mixtures—such as a mixture of iodide, bromide, and chloride—could not be titrated potentiometrically. It is possible, however, since the solubility of the silver halides is different enough so that the three are precipitated one after another with little coprecipitation. As the precipitation of each halide nears completion, there is a corresponding increase in the rate of change in the potential. Thus, three inflection points are noted in the graphed curve. Such a curve is obtained by plotting potential values against the volume of titrant used. Figure 3-2 illustrates this curve and shows the three break points.

In the portion of the above-mentioned titration curve corresponding to a relatively large change in potential, there is a point at which the curve changes its direction of curvature. This point, where direction changes, is an inflection point or break point. Ideally, the break point occurs at the equivalence point of the titration. However, in some cases this point may be displaced from the true equivalence due to a bias in the analysis. If such is the case, you may need to analyze known samples to determine an appropriate correction.

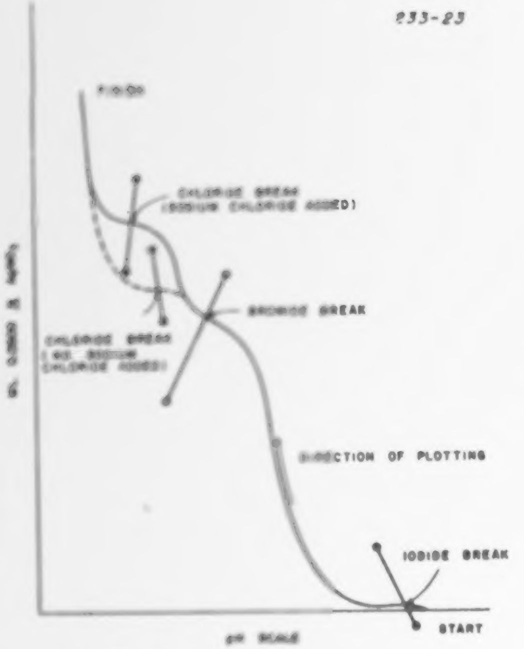

Figure 3-2. Typical bromide titration curve.

Silver nitrate titrations, such as the one shown in figure 3-2, may cause a problem in that it is difficult to attribute a specific inflection point to a specific halide. To clarify, the first break should be that of iodide because it has the lowest solubility. If very little or no iodide is present, the bromide and chloride breaks may almost merge. When this happens, one break may be confused with the other. We said that little or no iodide or chloride is present. The formula may not call for inclusion of iodide or chloride, but these chemicals may be present in the water supply or may appear as a result of accidental, but not known contamination. In order to preclude any error in detecting an unknown chloride break when it is close to the bromide break, additional chloride can be added to the sample before titration. The result then is a definite chloride break separated from the bromide.

You will note by examining figure 3-2 that the exact break point may be difficult to find when one curve blends with another. The easiest method to locate the point is to use a concentric arc template. This template is a semirigid transparent device. A series of concentric-arcs are scribed on the template. A small hole is located at the common center. Locate the approximate position of the end point, which is the part of the curve representing the greatest rate of potential change (fig. 3-3). Place the template on the plotted curve so that one of the arcs is superimposed on the curve. Then make a dot on the graph through the small hole in the template. Now place the template on the curve on the other side of the approximate end point and repeat the procedures. The arc that best fits this curve is not necessarily the same one as previously used. Draw a straight line between the two dots. The point where the straight line intersects the curve is the break point.

Another means of finding the break point is by using the "delta" method. This method is appropriate if manual titration is employed and if tabulated titration data shows a sharp end point. The method may give an incorrect end point if any one of the tabulated readings is in error. The method is best applied to data which represents smooth symmetrical curves. It is fairly rapid since a plot on graph paper is not required. During titration, record the buret readings and corresponding meter readings for each added increment of titrant as illustrated in figure 3-2. The increment that causes the greatest change in meter readings indicates the end point. For most purposes, the end point is assured to be halfway between the two buret readings which show the greatest difference.

Exercises (636):

1. What are two reasons why potentiometric titration may have to be used?

2. The two electrodes used in potentiometric titration are the ______________ electrode and the ______________ electrode.
3. In a titration curve, the point at which the curve changes its direction of curvature is called the ______________ point or ______________ point.

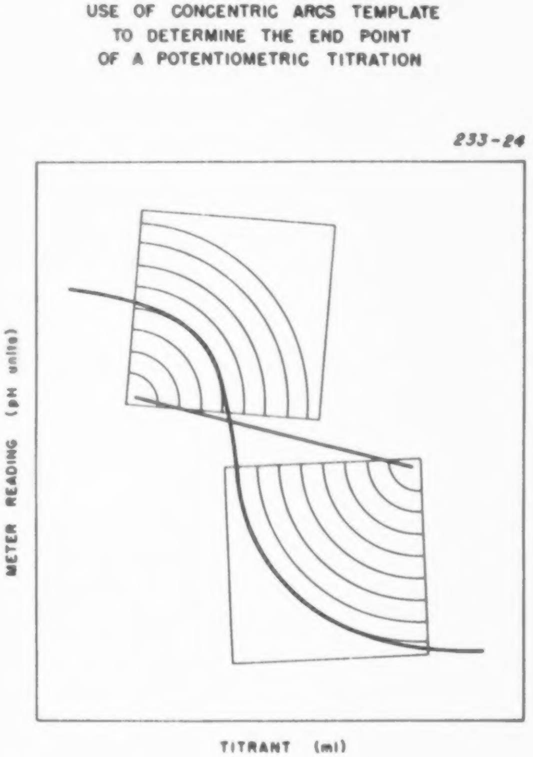
USE OF CONCENTRIC ARCS TEMPLATE
TO DETERMINE THE END POINT
OF A POTENTIOMETRIC TITRATION
233-24
METER READING (pH units)
TITRANT (ml)

Figure 3–3. Use of concentric arcs template to determine the end point of a potentiometric titration.

4. An easy method to find a break point when one curve blends with another is to use a ______________ ______________ ______________.

5. A method that may be used if manual titration is used and tabulated titration data shows a sharp end point is the ______________ method.

637. Specify how reagents are used properly.

Reagents. A titration involves the addition of measured amounts of a standardized reagent to a sample. The concentration of the chemical in a sample can be calculated from the amount of titrant (reagent) used to reach the end point of the reaction. All chemicals used in analytical work are called reagents because they react with other chemicals in a known manner. To guarantee the reaction as being standard or uniform, all chemicals must be "reagent grade." Such grading indicates that the chemicals are of the highest quality commercially obtainable. Be sure your chemicals are marked analytical reagent (AR) quality.

Make certain that your measurements are accurate. An expensive, pure, high-quality chemical must not be wasted. If you remove an AR chemical from its bottle, you cannot return any excess. Such a return could contaminate the rest of the chemical contained in the bottle.

Most reagents are mixed to exact strength concentrations (molar or normal). These strength concentrations are calculated from a percentage strength of the AR chemical and the amount of that percentage strength to give a final required dilution. The utmost care must be taken in preparing and standardizing reagent solutions. Freshly prepared reagent solutions must be checked and certified to within very close standardization tolerance values before they are used in chemical analyses.

Reagent chemicals of certified composition are carefully weighed on an analytical balance, transferred to volumetric glassware, dissolved in water, and diluted to a precisely known volume. The standard solutions thus prepared are of known composition and strength and are identified as having a specific reaction with some component of a photographic solution. An accurately measured sample of the solution being checked is allowed to react with a measured volume of reagent. You thus calculate the concentration of a specific component of the sample being tested. The accuracy of the method depends on the accuracy of the reagent. An error introduced into the reagent standardization will produce an error in subsequent analyses. Therefore, the utmost care must be taken in the preparation and standardization of reagent solutions.

Instructions for mixing most reagents are written for the preparation of a 1-liter quantity. Larger quantities can be mixed if they can be consumed before the expiration date. When no expiration date is given, it is implied that the reagent is stable or its proposed use is such that a critical concentration is not required.

Assume that you have prepared a reagent. You realize that errors in measurement can occur. Such errors may or may not be significant. No matter how careful you are, the mix is not perfect. Therefore, a typical reagent is usable at some plus or minus normality deviation from a nominal value. You must know these limits. In general, the accuracy of the standardized reagent is satisfactory if it is equal to the nominal value (for example, 0.1000, 1.000, etc.) within an allowable tolerance of ±0.6 percent, 99 percent of the time. Thus, two successive mixes of a reagent should never differ by more than 1.2 percent and only one batch in 100 will ever differ from the nominal value by more than 0.6 percent. If you are within tolerances, it is customary to use the nominal value in calculations. For example, a value of 0.1000 N is used for control purposes even though the true value differs by 0.6 percent and the value is actually 0.1006 N.

Exercises (637):

1. What are chemicals used in analytical work called?

2. Why should the utmost care be taken in the preparation and standardization of reagent solutions?

3. How do you allow for inevitable deviations from a perfect reagent mix?

4. A typical reagent is usable at what nominal value?

5. What is the implication when the reagent chemical shows no expiration date?

3-2. Quantitative Determinations

In order to accomplish a quantitative analysis of a solution (developer, fix, etc.), you need equipment, indicators, reagents, etc. In addition, you must have a sample of the solution being analyzed. Before we discuss the procedures used for specific analyses, let us consider the solution being analyzed. Notice we said a sample is needed. An HTA-3CM processor developing tank holds 115 gallons. You must withdraw a sample of the developer. How is this done?

638. State the purposes of selected procedures in solution sampling.

Solution Sampling. Chemical analyses are valid and useful only when the samples analyzed are representative of the solution. A correct analysis of a nonrepresentative sample may do more harm than good in controlling the process.

Processing solutions may be turbid or contain floating particles, dispersed oil droplets, a precipitate, etc. Even a clear solution may have a chemical concentration gradient between different points of the processing machine tank. For example, chemical composition of the solution where the film enters the tank is not the same as in other parts of the tank, even though the solution is agitated and recirculated. Therefore, a prescribed procedure must be used. All samples of a particular solution must come from the same location—such as a point near the location of the tank overflow. These samples are representative of the solution at the prescribed sampling point. Successive analyses based upon samples from the same point will indicate variations useful to establish a control action.

After you have taken a sample of the processing solution, let the sample bottle stand for about 10 minutes. This allows large particles to settle to the bottom and turbidity due to aeration to clear. An alternative procedure is to centrifuge the sample bottle. After sedimentation, withdraw the representative sample for analysis by using a pipet. Place the tip of the pipet about 1 inch below the surface of the solution of the sample bottle.

Occasionally it is necessary to shake a sample bottle for a specific reason. An example is when the concentration of the precipitate in a solution is to be determined. Shaking the representative sample enables you to calculate the concentration of the precipitate in terms of grams per liter. The analysis of the sample in this case is indicative of the entire sample and not just the dissolved chemicals.

Taking a sample is a simple procedure, but you must be certain that you do not introduce any new components. The following generalized procedures should be followed (use rubber gloves):

(1) Clean all syringes, bottles, and bottle caps with an acid-alcohol cleaning solution (use caution), followed by cleaning in a detergent solution. Rinse in tap water and drain.

(2) Identify each bottle with a label or identification ticket. (NOTE: Some paints or inks contain ingredients which may permeate polyethlene bottles and contaminate the sample.)

(3) Rinse the bottle or syringe (if used) twice with the solution to be sampled.

(4) Fill each sample bottle to overflowing to exclude air.

(5) Cap the bottle immediately to prevent any loss of volatile constituents.

(6) Rinse the outside of the sample bottle.

(7) Establish and use only one prescribed procedure for each specific solution sampling.

Sampling mix tank solutions by the surface method.

(1) Take the sample right after the mixer is turned off, while the solution is still moving.

(2) Submerge the sample bottle 4 inches below the surface of the solution and as near the center of the tank as possible.

(3) Rinse the bottle twice, then fill to overflowing. Be careful not to scoop in surface foam or surface particles.

Sampling mix tank solutions by the tap-off method.

(1) The "tap-off" is a short nipple and valve on the side of the tank or on the outlet line.

(2) Draw off and discard enough solution so that the final sample is representative of the tank solution.

Sampling of recirculated solutions from a closed system.

(1) Sample from a valve in the line. The valve is usually between the filters and the machine inlet.

(2) Open the valve fully and let the solution flow until it is free of air bubbles.

(3) Rinse the bottle twice, then fill to overflowing.

Sampling of recirculated solutions in an open system.

(1) Take the sample as described for solutions in closed systems.

(2) As an alternative, take a sample from the ballast tank using the surface technnique as described for mix tanks.

Sampling of nonrecirculated solutions.

(1) Insert a syringe 2 inches below the surface of the machine tank as close as possible to the tank overflow.

(2) Rinse the syringe and bottle twice before taking the sample. Do not aerate the solution during rinsing.

(3) Draw representative solution into the syringe. Expel the solution slowly at the bottom of the sample bottle to avoid aeration. Repeat until the sample bottle is overflowing.

At this point you have a sample of some photographic solution. You are now ready to make a quantitative analysis. Later in this chapter we will discuss how the results of analyses are used to evaluate new solutions, establish replenishment programs, make corrective additions, and certify solutions. For the moment, let us see how you make quantitative determinations of the most common photographic chemicals in solution. In general, quantities of developing agents decreases during use, while bromide increases.

There are many methods of quantitative analysis. Some are peculiar to specific military organizations, some are modified commercial procedures, and still others were developed by commercial laboratories. The procedures covered in this chapter are representative of typical analyses. Due to space limitations, we cannot cover all of the available procedures. For additional information we suggest you refer to such publications as AFM 52-2, *Principles and Practices for Precision Photographic Processing Laboratories* (obsolete, used as a training manual), or Eastman Kodak's *Chemical Control Procedures for Black-and-White Film Processing*.

Exercises (638):

1. Why is the sampling procedure as important as the later analysis of the sample?

2. Why must all samples of a particular solution come from the same location?

3. Why is it necessary to let a sample bottle stand for at least 10 minutes?

4. Why may it be necessary on occasion to shake a sample bottle?

5. Why must you use care in the type of labels you use on polyethlene bottles?

6. Why is the sample bottle filled to overflowing and then capped immediately?

7. When using a syringe to take a sample, what is the purpose of the slow expelling of the solution into the bottom of the sample bottle?

639. State the procedures used for developing agent determination (MQ developer).

Developing Agent Determination (MQ Developer). An MQ developing solution contains two developing agents. One agent is monomethyl-para-aminophenol. It has a number of names, depending on the manufacturer. Such names as Metol, Elon, Photol, Pictol, Rhodol, Graphol, Veritol, and Claritol. This developing agent is a crystaline white powder, moderately soluble in water. By itself it is rapid-working and produces soft negatives.

Metol is usually used with hydroquinone, which is known as para-dihydroxy-benzene. This is a slow but powerful developing agent. Hydroquinone is sensitive to temperature changes and is virtually inactive at temperatures below 55°F. Also, it may fog and stain at temperatures above 70°F.

The determination of both "Elon" (Eastman Kodak trade name) and hydroquinone in one solution is somewhat involved.

NOTE: This method is applied to any like agent (monomethyl-para-aminophenolsulfate), regardless of its trade name. The method (fig. 3-4) is called a cerimetric determination because it depends on a change of color to determine the end point at which the reaction of reduction-oxidation is complete. The Elon and hydroquinone are physically removed from the developer sample by mixing the sample with water-saturated ethyl acetate. Elon and hydroquinone are both soluble in the ethyl actate at a pH of 7.8. This pH is maintained by a phosphate buffer; the separation is done twice to guarantee the removal of Elon and hydroquinone. Ethyl acetate, containing both developing agents, is acidified with H_2SO_4 and sodium sulfate making possible a separation of the developing agents. The hydroquinone remains in the acetate solution while the Elon transfers to the aqueous solution. Each of these samples is treated by titrating the sulfato-cerate to a color change end point. The color is introduced by the use of the Ferrion indicator. End points of the titration are detected by the change in color from orange to light green or clear in fresh mixes and orange to a greenish-blue in seasoned mixes. The calculations include an estimation of Elon not extracted from the hydroquinone, and hydroquinone not extracted from the Elon. The calculations include a blank. This blank is the milliliters of cerate titrated into a solution containing no Elon or hydroquinone (HQ) before a color change is noted. Therefore, the blank quantity, different in both cases, must be subtracted from the total milliliters of cerate titrated before actual calculations can be made.

Pretitration calculations. As mentioned above, the developing extractions are not complete. Some of the Elon is retained in the ethyl acetate layer, and some of the HQ is extracted along with the Elon into the acid-sulfate reagent. The calculations must be corrected for this incomplete separation.

Considering just the ethyl acetate layer, experiments have shown that the 98.2 percent of the HQ and 1.6 percent of the Elon are retained in this layer. To calculate the HQ concentration from the ml of titrant required for the ethyl acetate layer, use the following equation: 98.2% of HQ = amount of HQ and Elon titrated in ethyl acetate layer minus the amount of Elon titrated in the ethyl acetate layer

and

$$\text{amount of Elon and HQ (expressed as HQ, gram/L)} \; \frac{\text{(ml cerate for ethyl acetate layer minus blank) (N cerate) (eq. wt. HQ)}}{\text{ml of sample}}$$

and

$$\text{(amount of Elon (expressed as HQ, gram/l)} \; \frac{\text{(1.6\%) (approx conc Elon) (55)}}{\text{(86)}}$$

In the above equation, the factor $\frac{55}{86}$ is the ratio of the equivalent weights of HQ to Elon. It is used here to convert the Elon in the ethyl acetate layer in terms of grams of HQ per liter. The blank value for the ethyl acetate layer was found to be 0.27 ml of titrant; that of the aqueous layer was 0.17 ml of titrant. The approximate concentration of Elon to be used in the equations is a standard value. An exact concentration of Elon is not needed because a difference of one gram of Elon amounts to an HQ difference of only 0.010 of a gram. After combining and simplifying for a 10-ml sample, the preceding equations become:

HQ (grams/l) = (0.280) (ml cerate for ethyl acetate layer) minus (0.010) (approx concentration of Elon) minus 0.08

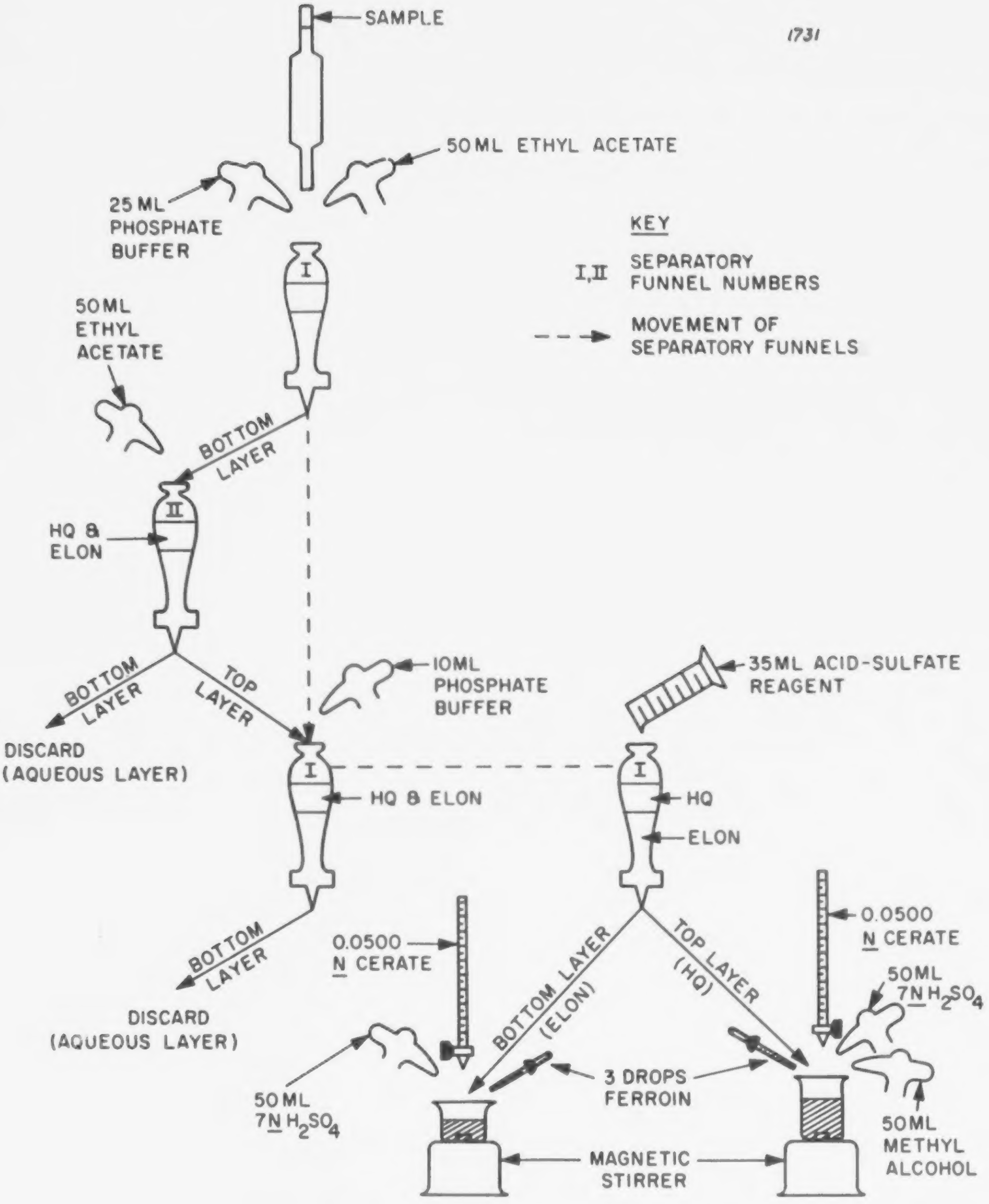
SAMPLE
1731
50 ML ETHYL ACETATE
25 ML PHOSPHATE BUFFER
KEY
I,II SEPARATORY FUNNEL NUMBERS
MOVEMENT OF SEPARATORY FUNNELS
I
50 ML ETHYL ACETATE
BOTTOM LAYER
II
HQ & ELON
BOTTOM LAYER
TOP LAYER
DISCARD (AQUEOUS LAYER)
10 ML PHOSPHATE BUFFER
35 ML ACID-SULFATE REAGENT
I
HQ & ELON
I
HQ
ELON
BOTTOM LAYER
DISCARD (AQUEOUS LAYER)
0.0500 N CERATE
BOTTOM LAYER (ELON)
TOP LAYER (HQ)
0.0500 N CERATE
50 ML 7N H2SO4
3 DROPS FERROIN
50 ML 7N H2SO4
50 ML METHYL ALCOHOL
MAGNETIC STIRRER

Figure 3–4. Procedure for Elon/hydroquinone determination.

In a similar way, the concentration of Elon is calculated from the volume of cerate required for the aqueous layer. The aqueous layer contains 98.4 percent of the Elon and 1.8 percent of the HQ. Thus:

98% of the Elon = amount of the Elon and HQ titrated in the aqueous layer minus the amount of HQ titrated in aqueous layer

and

$$\text{amount of Elon (expressed as Elon in gram/L)} \quad \frac{\text{(ml cerate for aqueus layer minus blank) (N cerate) (eq. wt. Elon)}}{\text{ml of sample}}$$

and

$$\text{amount of Elon (expressed as Elon Grams/1)} \quad \frac{(1.8\%)\ \text{(approx concentration HQ)}\ (86)}{(55)}$$

When using a 10-ml sample, these equations become:

Elon (grams/1) = (0.437) (ml cerate for aqueous layer) minus (0.029) (approx conc of HQ) minus 0.08

Some precision in Elon analysis is lost by using a 10-ml sample. A more reliable Elon determination uses a 25-ml sample and only the Elon is titrated. When Elon and HQ are lower, a 25-ml sample may be more satisfactory for both determinations. If the HQ content exceeds 40 grams/1, the sample size for the HQ analysis should be reduced to 2.00 ml (for example, EK formula D–95R).

Reagents needed. Before you start the analysis procedure, prepare or have on hand a number of reagent and indicator solutions. The following are necessary to perform the Elon and HQ determination:

- Potassium monohydrogen-dihydrogen phosphate buffer, pH7.9, at 80°F.
- Water saturated ethyl acetate.
- 3.6 N sulfuric acid, H_2SO_4, containing 142 grams/1 sodium sulfate.
- 7.0 N sulfuric acid.
- Ferroin indicator.
- Methyl alcohol, CH_3OH, practical grade.
- Sulfato-cerate, 0.0500 N.

Exercises (639):

1. What two developing agents are found in an MQ developing solution?

2. What determination is applicable to these agents? Why?

3. How are the Metol and hydroquinone physically removed from the developer sample?

4. At what pH are Metol and hydroquinone soluble in ethyl acetate?

5. What buffer maintains this pH of 7.8?

6. What procedure makes possible the separation of the developing agents?

7. How is the sample treated to obtain the end point?

8. How are the end points detected?

9. Before you start the analysis procedure, what would you prepare or have on hand?

10. What is the purpose of the blank in the calculations?

11. After developing agent extractions, how much Elon is retained in the ethyl acetate layer and how much HQ is retained in the aqueous layer?

12. Before you start the analysis procedure, you should have on hand a potassium monohydrogen-dihydrogen phosphate buffer at what pH and at what temperature?

640. List the seven major steps for the determination of Elon and hydroquinone in one solution.

Extraction of hydroquinone and Elon. Hydroquinone and Elon extraction is performed using the following procedures.

a. Add 25 ml of potassium monohydrogen-dihydrogen phosphate buffer, pH 7.9, from a tip-in pipet to a 250-ml separatory funnel (No I in fig. 3-4).

b. If the salt content of the developer exceeds approximately 100 grams/1, add 25 ml of distilled water to prevent precipitation of the salts.

c. Pipet (wipe the pipet before leveling) 10.0 ml of developer into the funnel.

d. Add, from a tip-up pipet, 50 ml of water-saturated ethyl acetate to the funnel.

e. Shake the funnel briskly for 15 seconds; allow the layers to separate (30 seconds or more).

f. Transfer as completely as possible the lower (aqueous) layer to another 250-ml separatory funnel (No II in fig. 3-4) without losing any of the top layer, containing HQ and Elon.

g. Add, from a tip-up pipet, 50 ml of water-saturated ethyl acetate to funnel No. II.

h. Shake the funnel briskly for 15 seconds; allow the layers to separate (30 seconds or more).

i. Discard the lower layer. (A small amount of the lower layer may be left in the separatory funnel.)

j. Transfer the contents of separatory funnel No. II to separatory funnel No. I.

k. Add 10 ml of potassium monohydrogen-dihydrogen phosphate buffer, pH 7.9, from a tip-up pipet.

l. Shake briskly for 10 seconds and allow the layers to separate.

m. Discard as completely as possible the lower layer without losing any of the upper layer, containing HQ and Elon.

Separation of the two developing agents. The separation of the two developing agents is done using the following procedures.

a. Add, from a graduated cylinder, 35 ml of 3.6 N sulfuric acid containing 142 grams/l sodium sulfate to separatory funnel No. I.

b. Shake the separatory funnel briskly for 15 seconds and allow the layers to separate (30 seconds or more). The top layer (ethyl acetate) contains HQ; the bottom layer (water) contains Elon.

c. Discard the bottom layer only if the developer contains a ratio of hydroquinone to Elon greater than 5 to 1 (as in reversal process developers). If this is the case, prepare the top layer for titration of hydroquinone.

Preparation of a 25-ml sample for the extraction, separation, preparation and titration of Elon. The extraction, separation, preparation, and titration of a 25-ml sample of Elon is done using these procedures.

a. Add, from a tip-up pipet, 50 ml of 7.0 N sulfuric acid to a 250-ml beaker.

b. Transfer, as completely as possible, the bottom layer (containing Elon) into the 250-ml beaker without losing any of the top layer (containing HQ).

c. Add 3 drops of Ferrion indicator to the beaker. Before proceeding to the titration of Elon, prepare the top layer for titration of HQ unless the HQ has already been determined from a previous sample.

Preparation of the top layer for titration of HQ. The top layer for titration of a HQ preparation is performed using this procedure.

a. Add, from tip-up pipets, 50 ml of methyl alcohol and 50 ml of 7.0 N sulfuric acid to a 400-ml beaker.

b. Transfer the top layer to the 400-ml beaker.

c. Add 3 drops of Ferroin indicator.

Titration of the Elon. It is advisable to use the smallest possible buret that will contain the required amount of titrant. In this analysis, the Elon and HQ burets may be of different sizes. Use the following steps:

a. Place the beaker containing the Elon layer on the magnetic stirrer and stir at a moderate rate.

b. Immerse the tip of the buret into the sample and titrate with 0.0500 N sulfato-cerate at a moderate rate. (A 10-ml buret is usually most satisfactory when titrating Elon.)

c. When near the end point, withdraw the tip of the buret from the solution and reduce the rate of delivery to about 3 drops a second. Titrate to a greenish-blue color that persists for 15 seconds. (The turbidity which may appear near the end point does not interfere with the analysis.)

Titration of the HQ layer. Titrate the HQ layer in the same way as the Elon with 0.0500 N sulfato-cerate. Its end point is more pale green than bluish green. Some fresh mixes titrate to a clear solution at the end point. The turbidity which may appear near the end point does not interfere with the analysis.

Calculations. Using the readings you obtain in the titrations, you can make the necessary calculations. The approximate concentrations of HQ and Elon to be used in the equations are the standard values:

a. Equations for HQ content:

(1) For a 2-ml sample the equation is: (1.40) (ml cerate for HQ titration) minus (0.010) (approx conc of Elon) minus 0.38 = HQ, grams/l.

(2) For a 10.0-ml sample the equation is: (0.280) (ml of cerate for HQ titration) minus (0.010) (approx conc of Elon) minus 0.08 = HQ, grams/l.

(3) For a 25.0-ml sample the equation is: (0.112) (ml of cerate for HQ titration) minus (0.010) (approx conc of Elon) 0.03 = HQ, grams/l.

b. Equations for Elon content:

(1) For a 10.0-ml sample the equation is: (0.437) (ml cerate for Elon titration) minus (0.029) (approx conc of HQ) minus 0.08 = Elon, grams/l.

(2) For a 25.0-ml sample the equation is: (0.175) (ml cerate for Elon titration) minus (0.029) (approx conc of HQ) minus 0.03 = Elon, grams/l.

Exercises (640):

1. Give the seven major steps for the determination of Elon and hydroquinone in one solution.

641. State the purposes of sulfite in a developer solution and the method and importance of its determination.

Sodium Sulfite Determination in Developers. Sulfite in a developer solution serves multiple purposes:

a. It retards the reaction of oxygen with the developing agents of the Metol hydroquinone (MQ) type and thus acts as a preservative against oxidation.

b. It reacts with oxidation products of these developing agents: products formed either by reaction with the silver halides during development or with oxygen from the air.

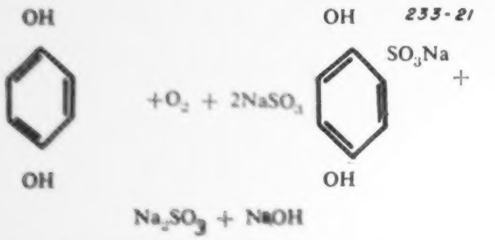

Figure 3-5. Reaction of sulfite with oxidation products of HQ.

The above action prevents the accumulation in the developer of products which would adversely affect the reactivity or stability of the developer and also prevents formation of staining decomposition products.

c. It exerts a solvent action on silver halides because of its ability to form a soluble complex with the silver ion, $Ag(SO_3)_2$.

Examine the previous functions in more detail so that you can see how the determination of sulfite is of considerable importance in compounding a developer and establishing a proper replenishment formula. Sulfite substantially cuts down the rate of aerial oxidation of hydroquinone and Metol. This action enhances the storage properties of developer solutions and increases the stability of solutions used in spray development. Over the range of sulfite concentrations generally used in commercial developers, the rate of oxygen oxidation varies inversely with the concentration of sulfite. Sulfite does affect the photographic properties of the developer, however, and you must take this into consideration when determining the optimum amount to be used for a particular developer. For example, you can obtain a definite increase in stability toward aerial oxidation by increasing the sulfite concentration in a positive developer of pH 10 from 40 to 100 g/1, but the fog is increased and gamma is decreased. A study of spray processing systems has shown that 40 g/1 is about the optimum sulfite concentration for the positive developer. On the other hand, the high sulfite concentration (100 g/1) is advantageous in the negative developer, where development is carried to a lower gamma and the high sulfite content improves graininess characteristics.

Sulfite reacts with the oxidation products of Metol and hydroquinone to form the corresponding sulfonates. These sulfonates are colorless, soluble compounds which are weak developers themselves but are less active than the parent compounds. The reaction of hydroquinone with oxygen in the presence of sufficient sulfite is illustrated in figure 3-5.

The reaction stated in the previous text tends to increase the pH of the solution. The reaction with silver bromide in the presence of sulfite is illustrated in figure 3-6.

Acid is liberated in this reaction, which accordingly tends to decrease the pH of the solution. The reactions of Metol in the presence of sulfite follow similar courses. A Phenidone developing agent, on the other hand, does not form a sulfonate. The sulfite is not as effective as a preservative for Phenidone as it is for Metol and hydroquinone.

The solvent action of sulfite on silver halide can influence the course of development in a number of ways. The mild solvent action appears to increase the rate of development of grains in the low-exposure region so that it approaches the rate of development in the more highly exposed regions in many emulsions. This produces an increase in emulsion speed, measured for a fixed gamma, if development is not pushed too near the maximum gamma. It has been found that the speed obtained in a Kodak D–76-type developer which contained an addition of 1 g potassium bromide per liter was decreased from two to three times by decreasing the sulfite concentration from the normal 100 g/1 to 25 g/1. On the other hand, if the activity of the developer is too low, the solvent action of sulfite can cause a considerable change in the character of development. Solution-physical development is marked, and improved graininess results, but at the expense of a loss in speed.

Reagents and indicator. Let us look at a method of sulfite determination. The method uses a color change to indicate the end point. The following solutions must be prepared to conduct the analysis:

- A 0.1–N iodine solution.
- Concentrated hydrochloric acid.
- Starch indicator (1 percent).

Procedure. Perform the following steps to determine the sulfite concentration:

(1) Place 25 ml of the 0.1–N iodine solution into a 250-ml Erlenmeyer flask.

(2) Add 5 ml of concentrated hydrochloric acid and 50 ml of distilled water.

(3) Fill a 10-ml buret with the developer sample and titrate into the flask until the brown color of the iodine is bleached to the color of light straw.

(4) Add 2 ml of the starch indicator. The solution will turn blue. Continue titration until the blue color disappears.

You are now ready to calculate the sulfite concentration. Use the following equation:

$$\frac{(\text{ml iodine})\ (\text{N of iodine})\ (63)}{\text{ml of developer}} = \text{grams/l of sulfite}$$

As an example, if 25 ml of 0.1–N iodine was used and 5.65 ml of developer was required to reach the end point, the calculation is as follows:

$$\frac{(25)\ (0.100)\ (63)}{5.65} = 27.9 \text{ grams/l of sulfite}$$

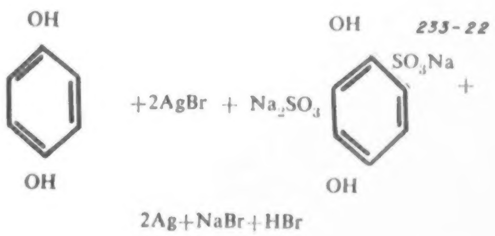

Figure 3–6. Reaction of HQ with AgBr in presence of sulfite.

Exercises (641):

1. Why is the determination of sulfite of considerable importance in compounding a developer?

2. What happens when sulfite reacts with the oxidation products of Metol and hydroquinone?

3. What influence does the solvent action of sulfite have on silver halide?

4. What method does the sulfite determination use? Give the steps.

642. Give the purpose and an effect of sodium carbonate in a developer, the importance of its determination, and the procedures used in the carbonate determination.

Sodium Carbonate Determination in Developers. Sodium carbonate is the most commonly used alkali in developers. Either the anhydrous or the monohydrated is used. Carbonate in a developer acts as an accelerator and activator of the developing agent. An increase in the pH of the developer generally causes an increase in the rate of development—at least over some range of pH—and hence a decrease in the time required to obtain a particular density or gamma. Either strong or weak alkalies may be used. If a strong alkali is used, a small amount is used. It is often more desirable to use a large amount of a weak alkali which provides a buffering action. In either case, the objective is establishment and maintenance of some specific pH value.

Another function of the accelerator is to induce softening and swelling in gelatin. The higher the pH, the more the gelatin swells. This allows the developer solutions to permeate the emulsion and permits the reaction products to diffuse out. If the pH is excessively high, the emulsion may soften and swell to a point where it is easily damaged. When it is necessary to use strong alkalies, it is customary to use specially hardened emulsions.

Developer activity is closely related to the pH value. The following shows the pH values for representative developer types:

- Caustic process developer = 10.5 to 11.0.
- MQ carbonate developer (paper) = 10.0 to 10.3.
- MQ borax fine grain developer = 9.2.
- Metol or p-phenylenediamine extra fine grain developer = 6.9 to 9.0.
- Amidol (acid) = 4.0 (This is the only common developing agent that can function in an acid environment.)

The pH values of some of the more common alkalies are shown below:

- Sodium hydroxide = 12.6 +.
- Potassium hydroxide = 12.6 +.
- Tri-sodium phosphate = 11.0 +.
- Sodium carbonate = 10.0 +.
- Kodalk = 9.0 +.
- Borax = 8.0 +.
- Sodium sulfite = 7.0 +.

The pH of a developer solution is important and it must be maintained at a specific value throughout development. Through replenishment you add accelerator as needed. The following method of sodium carbonate (most common accelerator chemical) quantitative analysis may be used. This procedure does not differentiate between carbonates and bicarbonates but merely gives the total carbonates. It is necessary to correct for the alkali contribution of the sodium sulfite present in the developer. Therefore, the carbonate analysis is preceded by a sulfite analysis.

Reagents and indicator. For this analysis:

a. Dissolve 0.10 gram of methyl orange and 0.25 gram of indigo carmine in 100 ml of distilled water.

b. Prepare a 1–N standardized hydrochloric acid solution.

Procedure. Use the following procedure to determine the total carbonate.

a. Into a 250-ml Erlenmeyer flask, place 100 ml of distilled water and add 4 drops of the methyl orange-indigo-carmine indicator (green when alkaline, violet when acid, gray when neutral).

b. Pipet (wipe the pipet before leveling) a 20.0-ml sample of developer into the flask.

c. Titrate with standardized 1-N hydrochloric acid to a gray end point.

For a developer containing monohydrated sodium carbonate and anhydrous sodium sulfite, the following calculations are used:

$$\text{grams/l of } Na_2CO_3H_2O = \frac{(\text{ml } HCl \times \text{normality } HCl) - (0.159 \times \text{grams } Na_2CO_3) \text{ per liter}}{0.323}$$

As an example, if 27.00 ml of 1.000-N HCl are required to neutralize 20 ml of developer containing 90 grams/l of sodium sulfite, the concentration of $Na_2CO_3H_2O$ is:

$$\frac{(27.00 \times 1.000) - (0.159 \times 90)}{0.323} = 39.3 \text{ grams/l}$$

For a developer containing no sulfite, use the equation:

$$\text{grams/l } Na_2CO_3 \cdot H_2O = \frac{(\text{ml } HCl)\ (\text{N } HCl)}{0.323}$$

Exercises (642):

1. What is the purpose of sodium carbonate in a developer?

2. What does the accelerator do to the gelatin?

3. Why is the determination and replenishment of the accelerator so important?

4. What acid is used for titration and what color indicates the end point?

643. State the reaction and indicators used to determine sulfite and carbonate combined in a developer and the procedure used to make this determination.

Combined Carbonate and Sulfite in Developer. It is desirable to quantitatively analyze both sulfite and carbonate at the same time. This determination is based upon the reaction of sulfuric acid with normal carbonate, bicarbonate, normal sulfite, and bisulfite. These reactions are shown in the following equations:

$$(1)\ 2Na_2CO_3 + H_2SO_4 = 2NaHCO_3 + Na_2SO_4$$

$$(2)\ 2NaHCO_3 + H_2SO_4 = H_2CO_3 + Na_2SO_4$$

$$(3)\ 2Na_2SO_3 + H_2SO_4 = 2NaHSO_3 + Na_2SO_4$$

$$(4)\ 2NaHSO_3 + H_2SO_4 = H_2SO_3 + Na_2SO_4$$

The end points of the reactions are determined by the use of two indicators. One is phenolphthalein and the other is a modified methyl orange.

Phenolphthalein is pink in the presence of sodium carbonate and colorless in the presence of bicarbonates, normal sulfite, and bisulfite. The end point of reaction (1) is indicated by the change of this indicator from pink to colorless. By using a standard acid and noting the exact amount needed to bring about this end point, we can calculate the carbonate content. The ml of titrant required in reaction (1) is just one-half that required to convert all the carbonate to carbonic acid.

Modified methyl orange is added after reaction (1) is completed. It is green in the presence of bicarbonate and normal sulfite but turns a neutral gray in the presence of bisulfite. The end point is noted at the completion of reaction (3). Thus, the modified methyl orange indicates that all of the carbonate and one-half of the sulfite has been titrated by the standard acid.

If a developer which contains sodium sulfite and sodium carbonate is titrated with a standard solution of sulfuric acid, first with phenophthalein and then adding modified methyl orange, the quantities of carbonate and sulfite may be calculated. (NOTE: 1 ml of 0.1000 N H_2SO_4 = 0.0053 gram Na_2CO_3 and 1 ml of 0.1000 N H_2SO_4 = 0.0063 gram Na_2CO_3).

Reagents and indicators. The following reagents and indicators are required:

- Phenolphthalein (0.1 percent).
- Sulfuric acid (0.1 N).
- Methyl-orange indicator.

Procedure. Perform the following steps:

a. Using a pipet, place a 25.00-ml sample of developer in a 500-ml volumetric flask and dilute to 500 ml. Mix thoroughly.

b. Pipet 25.00 ml of the diluted sample into an Erlenmeyer flask; add about 75 ml of distilled water and 5 drops of 0.1 percent phenolphthalein.

c. Titrate with 0.1–N sulfuric acid until the pink color disappears.

d. Record the volume of acid titrated. This is the "P" value in the calculation formula.

e. Add 5 drops of modified methyl orange indicator.

f. Continue titrating with 0.1–N sulfuric acid until the color changes from green to neutral gray. Passing the end point produces a purple color.

g. The total volume of acid used is the "T" value in the calculation formula.

h. Calculate the carbonate and sulfite content.

Compute your results using the following equations:

$$\frac{2P\ (\text{normality of acid})\ (53)}{\text{ml sample of developer}} = \text{grams/l } Na_2CO_3$$

$$\frac{2(T - 2P)\ (\text{normality of acide})\ (63)}{\text{ml sample of developer}} = \text{grams/l } Na_2SO_3$$

P = ml sulfuric acid used for phenolphthalein.
T = total acid titrated.

Exercises (643):

1. The determination of sulfite and carbonate combined in a developer is based on what reaction?

2. The end points of these reactions are determined by what two indicators?

3. What is the significance of the "T" in the calculation formula for carbonate and sulfite content?

644. State the critical nature and selected characteristics of bromide in a solution, the typical procedure for

bromide determination, and a significant development in the determination procedure.

Bromide Determination in Developer. Since the bromide in developing solutions increases as the solutions are used and since bromide acts as a restrainer, the amount of this chemical that is permitted to remain in the developer is quite critical. You quantitatively analyze for other chemicals to determine to what extent they have been exhausted, but you analyze for bromide content to find out how much it has increased over the original amount. The amount of bromide increase is a key factor in computing a replenishment formula.

Potassium or sodium bromide is often added to the developer solution in amounts varying from a few tenths of a gram to a few grains per liter. Bromide, in this concentration range, decreases the rate of fog development to a relatively greater extent than it decreases the rate of image development in an active developer, and it thus acts as a fog restrainer. The decrease in the rate of image development generally is relatively greater in the region of low exposure than in the region of high exposure. Hence, if you carry development to equal gamma values in solutions of different bromide content but otherwise equal composition, the entire characteristic curve is displaced toward larger exposure values as the bromide content is increased. On the other hand, if you adjust the development to obtain equal photographic speed, a solution which contains bromide gives a higher gamma than you would get from a solution which is identical except that it does not contain bromide.

The addition of bromide to the developer decreases the solvent action of sulfite. The equilibrium solubility of silver bromide decreases continuously with increasing bromide concentration, at least up to 10 g potassium bromide per liter. The rate of solution, however, decreases to a minimum at about 1 to 2 g potassium bromide per liter, and increases again at higher bromide concentrations. The rate of solution appears to be more important than equilibrium solubility with regard to the effect of sulfite on image tone and on the formation of dichroic (having the property of transmitting two colors) fog. Hence both fog formation and image tone may be adversely affected by the addition of too much bromide to the developer.

Soluble iodide in very small amounts acts as a fog restrainer in an active developer. Iodide also retards image development, and its effect on the rate of both image and fog development is much greater than that of a corresponding amount of bromide. Large amounts of iodide can seriously restrain both development and fixation.

Reagents and indicator. A typical procedure for bromide determination is the titrimetric method which depends on a color change to signal the end point. The following are the necessary reagents and indicator used to perform a bromide analysis:

- Nitric acid, concentrated.
- Metanil yellow, 0.2-percent solution.
- Silver nitrate solution (14.27 grams/1).
- Potassium bromide, 1-percent solution.

Procedure. The procedure used to make this bromide analysis is as follows:

a. Place a 100-ml sample in a 300-ml flask.

b. Add 100 ml of distilled water.

c. Add 15 ml of concentrated nitric acid (enough to neutralize the developer and about 10 ml excess).

d. Add 4 ml of 0.2-percent metanil yellow. The sample should now be red.

e. Add 10 ml of a solution containing 10 grams/1 of potassium bromide.

f. The treated sample in the flask is titrated with a solution containing 14.27 grams/1 of silver nitrate. Immediately upon addition of the silver nitrate, the sample will turn blue.

g. Titrate until the end point is reached. The color change is from blue-black to the original red and the silver bromide precipitate will coagulate.

The known quantity of potassium bromide is added to the sample to provide a sufficient amount of precipitate to insure a definite end point. This addition is not necessary when analyzing developers containing more than 1 gram/liter of potassium bromide.

The standard solutions are made up so that the value of bromide in the sample may be determined by dividing the net consumption of silver solution by 10. For example, if 28.50 ml of silver nitrate solution are required to react with the 100-ml sample containing 10 ml of standard potassium bromide solution, then:

$$\frac{(28.50 \text{ ml } AgNO_3) - 10.00 \text{ (ml KBr)}}{10} =$$

$$\frac{18.50}{10}(AgNO_3) = 1.85 \text{ grams/l KBr}$$

(NOTE: The 10.00 ml KBr is subtracted only where that amount is added to increase the KBr content of the sample.)

Exercises (644):

1. Why is the amount of bromide permitted to remain in a developing solution a critical factor?

2. What does the addition of bromide to the developer do to the solvent action of the sulfite?

3. What is the typical procedure for the bromide determination?

4. What two changes take place when the end point of titration is reached?

645. Specify the critical nature of sodium carbonate that requires its careful assaying when it is used as an alkali in a developer solution.

Assaying Chemicals. An important function of analysis is to assay the quality of photographic chemicals. Let us cover a specific example. Sodium carbonate, the most extensively used alkali in developer solutions, may vary in alkalinity between batches. If this variation is significant, its use will not produce the expected results unless the degree of variation is known and compensated for.

The requirement of the sodium carbonate is that it produces a pH known to give good results. Therefore, new or suspected batches should be compared to an acceptable "standard" batch according to the following procedure:

a. Select a reference standard from a batch of sodium carbonate known to produce good results. A considerable quantity, say 25 pounds, should be set aside for use as needed. The "standard" should be stored in airtight containers to protect it from the atmosphere.

b. On an analytical balance, weigh out exactly 6.00 grams of the reference standard.

c. Place the weighed standard in a 250-ml beaker and add 100 ml of distilled water (measure by pipetting). Dissolve thoroughly.

d. Adjust the temperature of the reference standard and measure its pH. Record the pH and the temperature.

e. On the analytical balance, weigh exactly 8.00 grams of the sodium carbonate to be tested.

f. Pipet exactly 100 ml of distilled water into a second 250-ml beaker.

g. Place the beaker of distilled water on a magnetic mixer and insert the electrodes of the pH meter. Using a clean scoop or spatula, add the sample a few crystals at a time to the water. When the pH of the sample approaches that of the reference, adjust the temperature to match that of the reference. Take a pH reading with the mixer stopped. Continue adding minute quantities of the weighed sample, stirring and reading the pH until the pH of the sample exactly matches that of the reference.

h. On the analytical balance, weigh the unused portion of the 8.00-gram sample and subtract to find the weight of the sample and subtract to find the weight of the sample needed to match the pH of the 6.00-gram reference standard.

The carbonate content of developer formulas using the new batch can now be adjusted by multiplying the weight of sodium carbonate by the factor obtained from the formula:

$$\frac{\text{Weight of assayed sample for required pH ``K''}}{6.00}$$

where "K" is the pH determined for the reference standard.

Exercises (645):

1. What is the characteristic of sodium carbonate that makes it necessary to assay its photographic quality?

646. State the advantages of using Phenidone as a substitute for Metol.

Phenidone Determination. Phenidone (1-phenyl-3-pyrazolidone) is a photographic developing agent which offers some advantage as a substitute for Metol in certain situations. Phenidone is Ilford's trade name and it is a proprietary developing agent. It is more energetic than Metol; thus, less of it is required in the developer formula. Phenidone resists exhaustion and can be used longer than MQ developers. Also, its toxicity is less than Metol.

When used with high-speed emulsions, Phenidone has a tendency to produce fog. The addition of an antifoggant (such as benxotriazole) lowers this tendency to an acceptable minimum. Phenidone is a low contrast developing agent that can be used in place of Metol at about 1/10 of the Metol concentration in most of the MQ systems. Some of the advantages of such substitution are:

- Less sensitivity to changes of bromide concentration.
- Attainment of comparable MQ developer activity at lower pH values, thus reducing the rate of aerial oxidation.
- Reduced induction period.
- Simplified replenishment control.

In explanation of the above reduced induction period, Phenidone is regenerated by hydroquinone in the developing process. Changes in concentrations of the other chemicals in the pH value can be determined, and compensation for the small loss of Phenidone during processing requires only a slight increase above the original amount. Tests show that a 10-percent increase of Phenidone in a replenisher is sufficient for most continuous replenishment systems.

As an example of a formula using Phenidone, the Air Force desired to formulate a low contrast developer to be used for rapid processing (90°F.) of high contrast aerial reconnaissance films. The developer also was to maintain unity gamma with aerial duplicating films under continuous processing. The desired operating parameters of the developer were that it:

- Produce gammas from about 1.0 to 1.5 and maintain rated emulsion speed.
- Be stable at 90°F. to permit high temperature processing.
- Be essentially nontoxic and nonallergenic.
- Be nonstaining to produce black silver.
- Be capable of being packaged in metal containers.

The developed formula, as a result of this successful research, consisted of the following chemicals:

Water	750 cc
Sodium sulfite	100 grams
Hydroquinone	3.0 grams
Phenidone	0.2 grams
Sodium carbonate (monohydrate)	3.0 grams
Sodium tetraborate	7.8 grams
Potassium bromide	1.0 grams
Water to make 1,000 cc	

Tests indicate that this developer is best used with Kodak Plus-X Aerecon film; Kodak Fine Grain Duplicating film

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(SO-278); Kodak High Definition film (SO-243); and type 1A, Class G-2 films. The developer can also be used for processing at 68°F., although it produces higher contrast results. Figure 3-7 illustrates the result of sensitometric tests of Plus-X Aerecon film processed at 90°F. in this Phenidone-hydroquinone developer. Compare this series of curves with the ones illustrated in figure 3-8, which show the result of processing the same film at 68°F. in the same developer.

Exercises (646):

1. What is the advantage of using Phenidone as a substitute for Metol?

647. State the method of Phenidone determination by an indicator and the procedures used to make this determination.

Phenidone Determination (Indicator). This method of Phenidone determination relies upon a color change to determine the end point.

Reagents. The following reagents are required:

- Chloroform.
- Glacial acetic acid.
- A 3.0-N hydrochloric acid solution.
- A 7.0-N sulfuric acid solution.
- Ethyl acetate, water saturated.
- Methyl alcohol.
- A 0.0500-N sulfato-cerate solution.
- Ferroin indicator.
- A 1.8-M ferric chloride solution.

Procedure. Use the following procedure to make this Phenidone determination:

a. Add 150 ml of chloroform and 4 ml of glacial acetic acid to separatory funnel number 1.

b. Pipet 50 ml of the developer sample into the funnel and shake for 30 seconds. Allow the layers to separate.

c. Drain the lower layer into funnel number 2. Discard the upper layer.

d. Add 100 ml of distilled water to funnel 2 and shake for 30 seconds.

e. Allow the layers to separate and drain the lower layer into funnel 3. Discard the upper layer.

f. Add 2 ml of 1.8-M ferric chloride and 10 ml of 3.0-N hydrochloric acid to funnel 3 and shake for 2 minutes. Allow the layers to separate and discard the lower layer.

g. Add 50 ml of chloroform to the funnel and shake for 30 seconds. After separation, discard the lower layer.

h. Repeat step 7.

i. Add 200 ml of distilled water and 25 ml of 7.0 N sulfuric acid to a 600-ml beaker and add 3 drops of Ferroin indicator.

j. Drain the contents of the funnel into the beaker and wash the funnel with water. Pour the washings to the beaker.

k. Titrate with 0.0500-N sulfato-cerate to a green yellow end point. Record the volume of titrant used to the nearest 0.01 ml. The calculation is now made by using the following equation:

$$0.0.757\ (\text{ml cerate}) - 0.02 = \text{Phenidone (grams/l)}$$

Exercises (647):

1. What does the Phenidone determination by an indicator rely on?

2. To what point of Ferroin indicator change do you titrate with 0.500-N sulfato-cerate?

648. State the characteristics of borates as accelerators in developing solutions.

Borates. A developer must be in an alkaline state in order to work. Also, the alkali used must be stable. Many alkalies can be used, ranging from strong to weak—for example, a strong hydroxide to a weak borax (sodium tetraborate) to Kodalk (sodium metaborate). The accelerator strength has a pronounced effect on the type of developer. A weak alkali is desirable when a relatively fine grain is desired, as it usually is in high altitude reconnaissance. A typical developer formula using borax is D-76 or Air Force developer No. 3.

To formulate a low-alkalinity developer, you can use a relatively strong alkali (hydroxide) in a small quantity. However, it is often more desirable to use a larger quantity of a weak alkali where the weighing is not as critical. Additionally, the chemical handling is much safer. The use of a weak alkali in larger quantities is advantageous since it will disassociate more slowly than a small quantity of a strong alkali. The neutralization of the hydrogen ions liberated during the development process by the action of the alkali provides a buffering action. The hydrogen ions lower the pH (increase the acidity) of the solution; and if they are neutralized as they are released, the pH remains constant.

You should be aware that a strong alkali does not necessarily give the same results as a weak one, even though you have made allowance for the different strength. Normally, you do not substitute a strong alkali for a weak one. Most of the developers used with aerial reconnaissance film are formulated so as to use the weaker alkalies. Since the reaction of the developer with silver halide liberates acid, the buffering action of the alkali (i.e., its ability to maintain a particular pH) is most important. If the buffering action is weak, the pH of the developer may decrease seriously during use with an attendant loss of activity.

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TIME	GAMMA	SPEED (B)	BASE + FOG	21st STEP
30 sec	0.48	50.0	0.07	1.02
45 sec	0.67	76.0	0.08	1.51
1 min	0.80	95.5	0.09	1.82
1 1/2 min	0.96	120	0.11	2.23
2 min	1.20	115	0.13	2.70
3 min	1.68	95.5	0.18	3.19

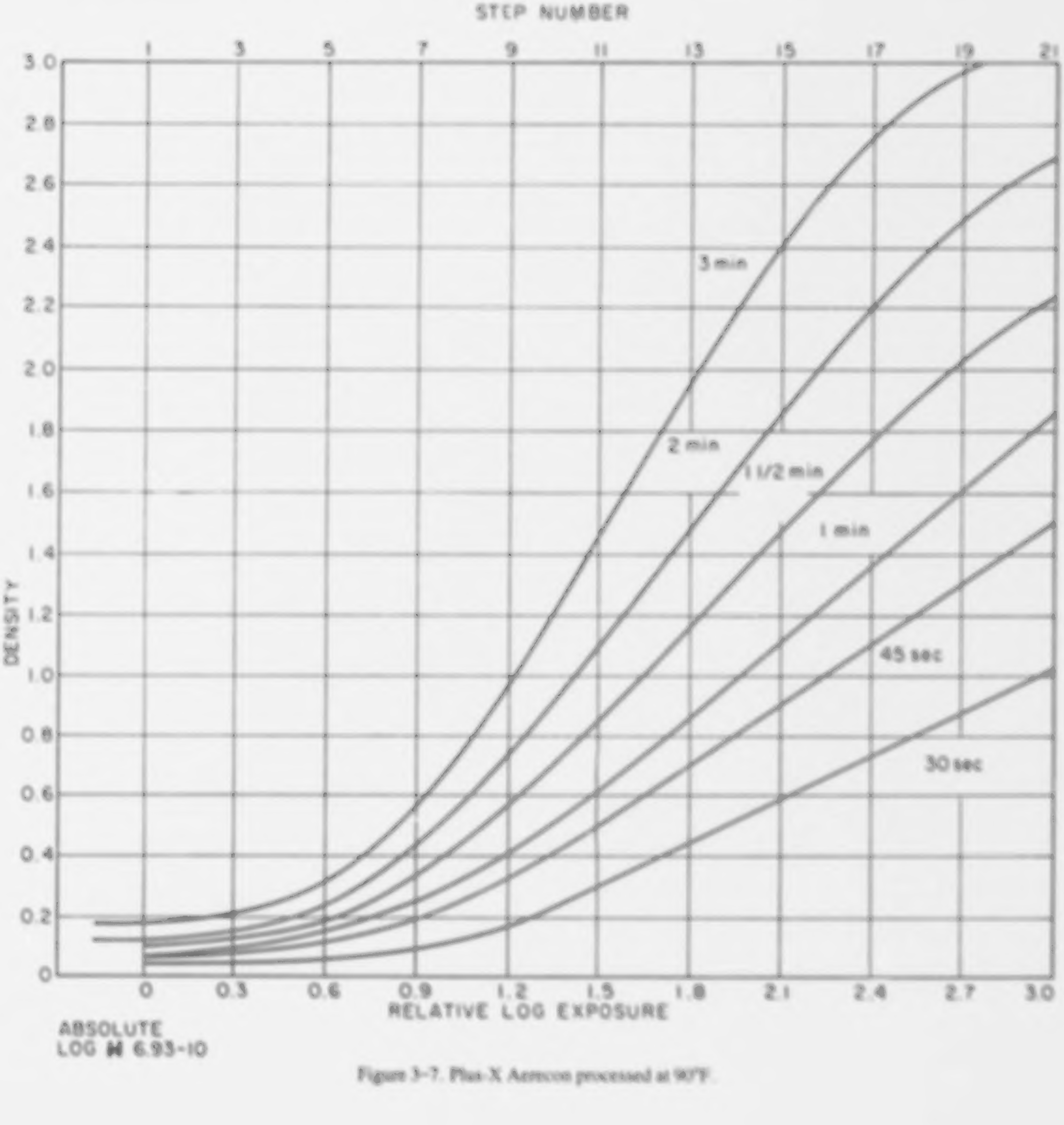

Figure 3-7. Plus-X Aerecon processed at 90°F.

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TIME	GAMMA	SPEED (B)	BASE + FOG	D. MAX
2 min	0.85	45.5	0.09	1.81
4 min	1.03	72.5	0.09	2.65
6 min	1.45	76.0	0.09	3.04
8 min	1.70	76.0	0.12	3.34
10 min	1.80	79.5	0.12	3.50
12 min	1.90	79.5	0.14	3.59

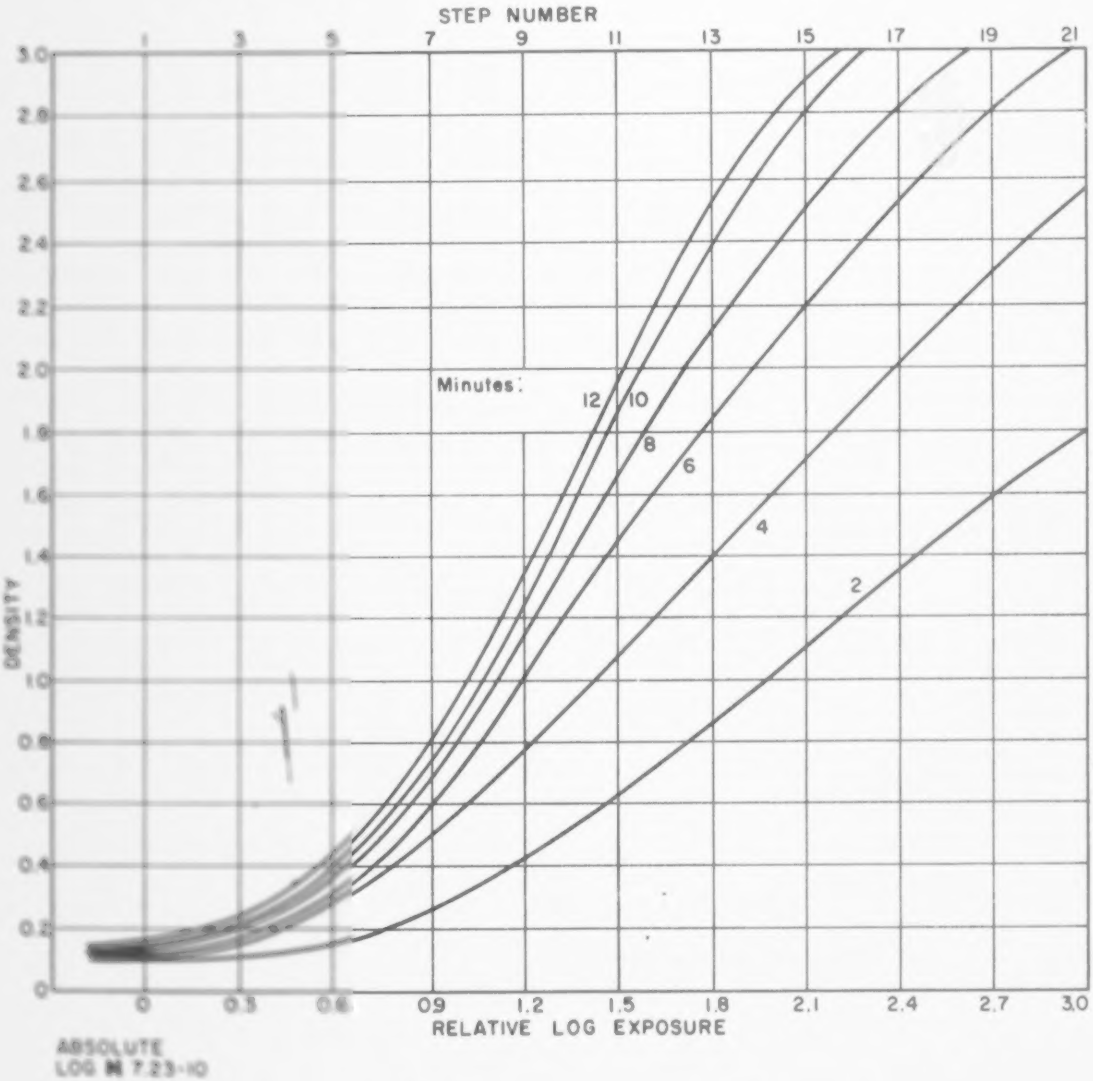


Figure 3–8. Plus-X Aerecon processed at 68°F.

Moreover, the pH of the solution within the layer of swollen gelatin during development determines the actual rate of development of the film. The pH of a poorly buffered solution may undergo much larger changes in this layer than in the bulk of the solution, particularly in heavy exposure areas. Thus, the sensitivity and contrast increase with increasing buffer capacity of the developer.

Borates in a developer. The use of borates as accelerators in a developer is not new. As far back as 1927, the MQ formula (D–76) using borax was introduced by Eastman Kodak. At that time it answered a need for a fine grain developer in motion picture work. Not only did it have fine grain capabilities, but it did not appreciably lower film speed and it allowed shadow areas to develop to maximum without making highlights too dense. The formula for D–76 is as follows:

Metol	2.0 grams
Hydroquinone	5.0 grams
Sodium sulfite (desiccated)	100 grams
Borax (granular sodium tetraborate)	2.0 grams
Water to make 1 liter	

A slight increase in reduction potential of a developing agent can be obtained by using Kodalk (sodium betaborate). The strength of Kodalk is between borax and carbonate. A typical formula using Kodalk is DK–50. Kodalk being slightly stronger requires the use of a potassium bromide restrainer as you can see by comparing this formula with D–76:

Metol	2.5 grams
Sodium sulfite (desiccated)	30 grams
Hydroquinone	2.5 grams
Kodalk	10 grams
Potassium bromide	0.5 grams
Water to make 1 liter	

Another formula using Kodalk is DK–20. Note from the formula that it is somewhat similar to DK–50. The major differences are the addition of sodium thiocyanate, which acts as a silver solvent, and deletion of hydroquinone. The solvent dissolves part of the silver grains, thus making them smaller. Following is the formula. Compare this with the previous one:

Metol	5.0 grams
Sodium sulfite (desiccated)	100 grams
Kodalk	2.0 grams
Sodium thiocyanate	1.0 grams
Potassium bromide	0.5 gram
Water to make 1 liter	

Borates used as buffers. In order to successfully use a pH meter, it must be calibrated before being put to use. This simply means that when the meter shows a solution is at a pH of, say, 6.5, the actual pH is 6.5. In order to apply any required correction to the meter reading, it will be necessary to measure some solution whose pH is known. For example, you can prepare a borax buffer and measure its pH. At a temperature of 70°F., the meter should indicate a pH of 9.21. If it does not, the instrument is readjusted until a correct reading is obtained.

A borax buffer solution is relatively simple to prepare. You must, however, be certain that the components are at a desired purity. For example, the distilled water should be at a neutral pH value of 7.0, but in no case should it be more than 7.5 or less than 6.5. The following steps are used in the preparation of a borax buffer:

a. Add 600 ml of distilled water to a 1-liter volumetric flask.

b. Add and dissolve 3.8 grams (± 0.1 g) of reagent quality crystalline sodium tetraborate, $Na_2B_4O_7 \cdot 10\ H_2O$ (borax).

c. Dilute to a 1-liter volume with distilled water. The buffer prepared in the above steps should use borax which conforms to requirements established by the National Bureau of Standards. A torsion balance is used to weigh the material. The solution should be used within 1 month. You may often get less than a month's use as it tends to mold easily.

The pH meter is standardized by using the above-prepared buffer. Note that temperature is a factor in this standardization. The pH scale dial is set to correspond to the values shown below.

°F.	*pH*	*°F.*	*pH*
60	9.27	71	9.21
61	9.26	72	9.20
62	9.26	73	9.20
63	9.25	74	9.19
64	9.25	75	9.19
65	9.24	76	9.18
66	9.23	77	9.18
67	9.23	78	9.18
68	9.22	79	9.17
69	9.22	80	9.16
70	9.21	81	9.16

Additional checks of a new borax buffer are necessary before it is considered usable. In general, the new mix of borax buffer is compared to values established during use of a previous batch. There should not be a difference of more than 0.02 pH between the old and the new at the same temperature. If the difference is greater than this, run another check. If the new buffer is still not acceptable, look for trouble in the equipment or contamination of the buffer solution. The reason the old buffer is used as a standard is because the laboratory system has been successfully operating (assuming this to be true) at indicated pH values.

Exercises (648):

1. Sodium metaborate has the advantage of yielding developers whose alkalinity is intermediate between ______________ and ______________.

2. When using developers with aerial reconnaissance film, why is it necessary to formulate a developer with borate alkalies?

Use of Chemical Analysis

YOU HAVE PREVIOUSLY studied many aspects of photographic chemistry, the use of laboratory equipment, preparation of analytical solutions, and procedures for various quantitative determinations. In effect, you have many bits and pieces of information. This information is collected and becomes a factor for certifying in-standard solutions, making corrective adjustments, controlling water quality, establishing a replenishment program, and evaluating a new solution.

In the previous chapter, you studied four chemical analyses of fresh solution mixes. You determined specific gravity, pH, total alkalinity, and total acidity. These tests, coupled with "sensi" tests, assured you that the fresh mix was good. It is apparent that these tests can also be applied when analyzing a mix which is in use.

4-1. Certifying That Solutions Are In-Standard

Let us consider specific gravity, pH, total alkalinity, and total acidity in regard to solutions that are in use. In some labs where the work is not too critical, these four analyses may be the only ones performed. As you previously studied, the analyses are applied to solutions in use. The comparison of fresh mix reading to a reading obtained from the used mix serves to provide certain information. As an example, assume that your processing machines uses a prewet tank before development. A certain amount of water from this tank is carried over to the developing tank. This increases the solvent and thus decreases the solute. This decreases the weight of dissolved chemicals and reduces the specific gravity. Let us examine this in greater detail.

649. State how to measure the total chemical content of a solution.

Specific Gravity. You have studied that specific gravity is the relative density of a substance (solution) as compared with the density of distilled water. In order to measure the total chemical content, you float a hydrometer in the solution. Depending on how high or how low it rides in the solution, it gives you a reading of how much heavier or lighter the solution is as compared to water. The scale in the hydrometer is calibrated for reference to pure or distilled water at 60°F. The scale division of 1.00 marks the depth to which the glass tube sinks in distilled water. For liquids heavier than water, the hydrometer has a scale reading downward from 1.00 to 2.00. For liquids lighter than water, the scale reads from 1.00 to 0.7.

The temperature of measurement should be specified and controlled in all specific gravity measurements because specific gravity of a solution is affected by temperature. An increase of 5°F. causes a decrease of 0.001 in specific gravity of most processing solutions. Standards of specific gravity for processing solutions are set by preparing mixes at 70°F. because many black-and-white processing solutions are used at that temperature.

The many individual applications of specific gravity can be left to your imagination. We mentioned water carryover. The actual dilution of developer is obtained by comparing the fresh developer to the one in use. Another application is the comparison of a fresh fixing bath to a used fixing bath. Since the silver content of the bath increases through use, it is logical to assume a change in specific gravity. The use of an argentometer is preferred, but, lacking equipment, specific gravity may be a sufficient indicator for your purpose. Through experience, you will establish upper and lower control limits for specific gravity of the various solutions needing such a check.

Most of the specific gravity readings you make during an operation are not always definitive of what is wrong. They simply indicate a change which can be the signal for further testing. If a developer in use is being replenished properly, specific gravity will be constant. If the flow of replenisher is accidentally stopped, a change of specific gravity will be evident. Replenisher flowmeters should also indicate the problem; but a backup check of specific gravity and pH (coupled with "sensi" strip processing) is desirable—especially since it can be made with practically no effort.

Exercises (649):

1. How do you measure the total chemical content of a solution?

2. How is the scale in the hydrometer calibrated?

3. Is temperature a critical factor when checking a solution?

4. State some of the many varied applications of specific gravity.

5. Does specific gravity reading give us a definitive answer?

6. What indication does a decrease in weight of the solute and an increase in the solvent of a solution give?

650. State how to maintain and monitor the pH value of a developer in processing control.

Alkalinity. Maintaining the pH value of a developer is one of the most important controls in processing. Since it is so important, it follows that it must be carefully monitored. A fresh mix of developer is evaluated and its pH is established. This value is maintained throughout processing. Samples of the developer are taken at intervals and quickly checked for pH. The speed of this check is a great advantage. The pH solution in use can be monitored during processing, and timely adjustments can be made to the solution. The pH is one of the most important factors in processing control. Let us review the effects of pH.

An increase in the pH (increase in the alkalinity) of the developer generally causes an increase in the rate of development—at least over some range of pH—and hence a decrease in the time required to obtain a particular density or gamma. The principal reason for this, for developers of the hydroquinone and Metol type, is that the ionized form of the agent is much more active as a developer than the nonionized form, and an increase in pH increases the concentration of the ionized form. The manner in which the developer molecule ionizes is by splitting the hydroxyl group.

Metol ionizes to form a singly charged ion. Hydroquinone has two hydroxyl groups and ionizes in two stages. The doubly ionized form is the most active as a developer, and the pH dependence of the rate of development by hydroquinone is greater than that by Metol. Phenidone is active in its nonionized form, but it ionizes to a significant extent at high pH. The pH dependence of the rate of development by Phenidone is less than by Metol.

At high pH, the variation in rate with pH becomes small for all three developers. This is partly because the degree of ionization is high and further increase in pH produces little increase in the concentration of the active ion, and partly because diffusion of the developer through the gelatin becomes more important as the rate of development increases. At sufficiently high pH, the rate of the chemical reaction becomes so great that the actual rate of development is largely controlled by the slower rate of diffusion through the gelatin layer.

The time required to obtain a given gamma generally decreases as pH increases over a range of 8.7 to 9.6; yet experiments show that the magnitude of the decrease depends upon the Metol-hydroquinone ratio and upon the bromide concentration. In a pH range of 10 to 11, the time decreases with increasing pH for a developer which contains 2 g KBr/1, but increases for a developer which contains only 1 g/1. Fog generally increases relative to image development as the pH increases, at least in higher pH ranges.

Usually, the activity of a developer does not depend very much upon the nature of the alkali used to obtain a particular pH. Sodium carbonate is commonly used to obtain pH 10 to 11. Sodium metaborate can be used for pH around 10 and below, and borax (sodium tetraborate) or borax plus boric acid for pH 8 to 9. The borates are excellent buffers in the pH range of 8 to 10, although they are not satisfactory for use with developing agents which have adjacent hydroxyl or hydroxyl and amino groups (ortho position) in the benzene nucleus, such as catechol and pyrogallol. Borate forms a complex with these agents and thus greatly decreases their activity. Borate does not form a complex with agents which have active groups in the paraposition, such as hydroquinone and Metol, or with Phenidone. Sodium sulfite, or a mixture of sulfite and bisulfite, are used as the sole alkali in certain fine-grain developers in the pH range 7.8 to 9.0. Amines are used as alkali in certain developers. Both sulfite and amines have an action in addition to that of simply establishing a definite pH. Both act as silver halide solvents and the amines can act as development accelerators.

The amount of alkali needed to obtain a definite pH depends on the developing agent and its concentration, as well as on the amount of sodium sulfite used. Metol, which contains a half mole (a measurement in terms of molecular weight) of sulfuric acid per mole of developing agent, requires enough alkali to neutralize the acid, in addition to whatever is needed to raise the pH to the desired value. At high pH, alkali is needed for the ionization of the hydroxyl groups of both Metol and hydroquinone.

Since the reaction of the developer with silver halide liberates acid, the buffering action of the alkali (i.e., its ability to maintain a particular pH) is most important. If the buffering action is weak, the pH of the developer may decrease seriously during use, with attendant loss in activity. Moreover, the pH of the solution within the layer of swollen gelatin during development determines the actual rate of development of the film, and the pH of a poorly buffered solution may undergo much larger changes in this layer than in the bulk solution, particularly in the areas of high exposure level. The photographic effect of such a change in pH is that the sensitivity and contrast obtained with developers of a given solution pH increase with increasing buffer capacity of the solution.

By analyzing the above effects of pH, you determine why the alkalinity of your particular developer has decreased during use. Such an analysis is largely dependent upon how quickly you can establish the pH while the machine is in operation. Previous readings with the same system have established upper and lower control limits. As your pH starts drifting toward either control limit, carefully monitor the shift. At some point you may have to take corrective action if the shift continues. The most appropriate correction is probably a change in replenishment. Do not ignore other possible contributory factors (temperature, replenishment supply malfunction, large expanses of heavily exposed film, etc.) that may cause temporary pH changes. Also, be sure that the analysis sample is taken from the same place in the machine; sample analysis is always made at a standard temperature, with the same pH meter, etc. In other words, standardize everything except the one variable you are striving to analyze.

Exercises (650):

1. How do you maintain and monitor the pH value of a developer?

2. An increase in pH of a developer generally causes an ______________ in the rate of development and a ______________ in the time required to obtain a particular density or gamma.

3. What happens to image development as the pH increases?

4. The amount of alkali needed to obtain a definite pH depends on what factors?

5. What is the importance of the buffering action on an alkali and its ability to maintain a particular pH?

6. How do you monitor a shift in pH?

7. List other possible contributory factors that may cause temporary pH changes.

8. What is the key word when running a sample analysis of the pH of a solution?

4-2. Making Corrective Additions

Chemical analysis is used to check all solutions before use to guarantee that they are properly mixed, to check during use to keep chemicals up to standard, and to locate troubles in faulty chemicals. The analysis is used as a bias for discarding solutions or for adjusting their composition to permit further use.

651. State the facets of chemical action and physical interaction in a photographic solution.

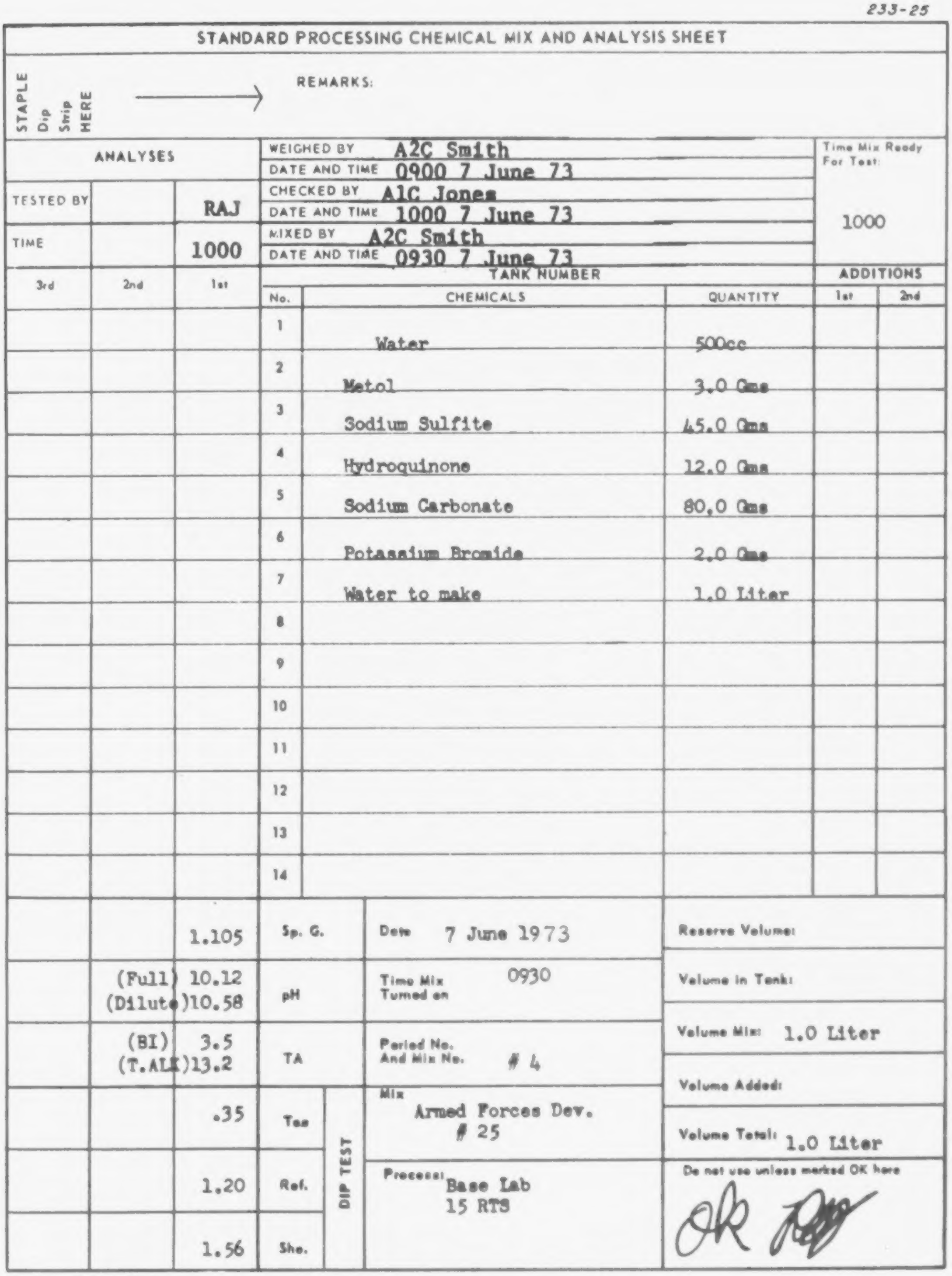
Chemical Action and Physical Interaction. Chemical analytical procedures, supplemented by "sensi" tests, are necessary for exact control of processing solutions. Solutions are maintained at chemical levels which are known to produce satisfactory tolerance limits. Chemical adjustments are made as necessary to keep solutions at their original composition. In emergency situations, it may be necessary to make temporary adjustments in temperature, agitation, machine speed, etc., in order to apply immediate corrective measures. When time permits, the chemistry is then adjusted.

As we have stated, a mix is certified against control data from previous experience. If the mix involves any modification on which you have no data, tests must be made and the results must be analyzed, evaluated, and given control limits. Control limits are based upon your laboratory requirements. Figure 4-1 illustrates an example of a typical form used in mixing and analyzing a batch of developer. A mixing and analysis sheet is used for certification of each batch of solution. When all this information is compiled, a permanent record can be made and used as a reference for future certifications. From these records, control limits are established.

Once the control limits are found, your only function is to perform routine checks to verify that the process is within limits. Even if a routine test falls out of limits, you should not be in a hurry to dump the mix—instead, repeat the tests. If the second test shows the same faulty results, investigate. Be sure you are using the correct film for "sensi" checks, check "sensi" strip development, check pH readings, etc. If everything still seems to be in order, the batch should have a complete analysis.

Sometimes an analysis will reveal a condition that can be remedied by modifying or altering the solution. After this is done, another series of tests are run. If these tests are satisfactory, the mix is certified for use. If the mix cannot be corrected, it is dumped. At no time is it used before certification is complete.

As a control chemist, you may be faced with altering the composition of one of your processing solutions. Revised formulas are often required for such reasons as changes in machine design, changes in emulsions, changes in mission requirements, etc. Changes in formulation to produce a desired result are based on a thorough knowledge of the purpose of each chemical in the solution and how each chemical is affected by other chemicals. Also, you must consider the many facets of chemical action and interaction with respect to temperature, agitation, exposure, etc. If you desire to modify an existing formula, you start your modification by first studying the results obtained by the formula you are using. This is a standard from which you will work. Such a study must note sensitometric results of the old process.



233-25

STANDARD PROCESSING CHEMICAL MIX AND ANALYSIS SHEET

STAPLE Dip Strip HERE → REMARKS:

WEIGHED BY A2C Smith
DATE AND TIME 0900 7 June 73
CHECKED BY A1C Jones
DATE AND TIME 1000 7 June 73
MIXED BY A2C Smith
DATE AND TIME 0930 7 June 73
Time Mix Ready For Test: 1000

ANALYSES							
TESTED BY		RAJ					
TIME		1000	TANK NUMBER			ADDITIONS	
3rd	2nd	1st	No.	CHEMICALS	QUANTITY	1st	2nd
			1	Water	500cc		
			2	Metol	3.0 Gms		
			3	Sodium Sulfite	45.0 Gms		
			4	Hydroquinone	12.0 Gms		
			5	Sodium Carbonate	80.0 Gms		
			6	Potassium Bromide	2.0 Gms		
			7	Water to make	1.0 Liter		
			8				
			9				
			10				
			11				
			12				
			13				
			14				

		1.105	Sp. G.		Date 7 June 1973	Reserve Volume:
	(Full) (Dilute)	10.12 10.58	pH		Time Mix Turned on 0930	Volume in Tank:
	(BI) (T.ALK)	3.5 13.2	TA		Period No. And Mix No. # 4	Volume Mix: 1.0 Liter Volume Added:
		.35	Tan	DIP TEST	Mix Armed Forces Dev. # 25	Volume Total: 1.0 Liter
		1.20	Ref.		Process: Base Lab 15 RTS	Do not use unless marked OK here OK
		1.56	Sha.			

Figure 4-1. Chemical mix analysis sheet.

Let's consider how one modification can have extensive effects on a solution; for instance, the desirability of raising the temperature of the developer to shorten development time. As you have studied, rate of development increases with an increase of temperature. Thus, you have shortened the development time, but this is not all. To begin, the shape of the characteristic curve will probably change. This may or may not be desirable. The rate of development in the low exposure-level areas is increased more than in the high exposure-level areas. The effective photographic speed accordingly increases with temperature if development is carried to a fixed gamma (below the maximum) if the fog does not increase excessively. If development is carried to a fixed fog level, speed decreases with increasing temperature. Shoulder densities are generally lower and the fog level higher when the temperature is increased and development is carried to a fixed gamma. The quantitative relations depend upon the developer composition and the photographic material used.

The dependence of the rate of development upon temperature can be expressed roughly in terms of the temperature coefficient. This coefficient is the ratio of the development rate at a particular temperature to the rate at a temperature 10° lower on the Centigrade scale, or 18° lower on the Fahrenheit scale. This coefficient is nearly constant over the practical working range for some developers and emulsions, but not all. If it is nearly constant, the equation

$$\log t = C - kT$$

is a useful working relation for extrapolation or interpolation. In this equation, T is the temperature, t is the time required to develop a particular gamma or image density, and k and C are constants which depend on the developer, the photographic material, and the temperature scale. The temperature coefficient may be as low as 1.3 to 1.5 for some developers, and as high as 3.0 to 4.0 for others.

Several factors may operate simultaneously to determine the net temperature dependence of development. For instance:

a. An increase in temperature increases the specific rate of the chemical reaction or reactions in development.

b. An increase in temperature increases the rates of diffusion of the developer components and reaction products through the emulsion layer. (Under some conditions, *a* is the primary factor which determines the temperature dependence; under other conditions, *b* is the primary factor. The rate of development by some solutions depends on both at intermediate temperatures.)

c. At constant pH, the degree of ionization of the organic developing agents which contain hydroxyl groups increases with increasing temperature. This means an increase in the concentration of the effective developing agent.

d. The pH of a buffer solution of fixed composition generally decreases with increasing temperature. (Thus *c* and *d* act in opposite directions, but *c* usually dominates.)

e. The quantitative effect of temperature may depend upon the amount and kind of exposure of the photographic material. The temperature dependence increases as the exposure level decreases.

f. Fog development is more dependent on temperature than is latent-image development.

g. The temperature coefficient of a developer is greater when it contains soluble bromide (e.g., potassium bromide) than when it does not (composition otherwise the same).

h. The temperature coefficient varies with the developing agent, and often decreases with increasing pH for a particular agent.

i. The temperature dependence varies to some extent with the photographic material.

j. The swelling of the gelatin increases with increasing temperature. The gelatin layer becomes increasingly soft, and may reticulate or even go into solution if the temperature is too high.

k. An increase in temperature sometimes causes an increase or a decrease in covering power (the ratio of density to mass of silver developed per unit area) and a shift toward a warmer image tone. These effects vary with the photographic material used and the developer.

From the previous textual segment, you can see that raising temperature does not necessarily produce only a decrease in development time. Other modifications you may desire must also be approached in a similar analysis. Complete tests must be conducted so that all facets of the process are checked out. In *f*, you noted that an increase in temperature increased fog. Thus, you may have to increase the amount of restrainer. However, an increase in restrainer may affect the characteristic curve, which, in turn, requires another chemical modification, and so on.

Exercises (651):

1. The rate of development is greatly affected by what physical characteristic?

2. What ratio is the temperature coefficient?

3. A rise in temperature of a solution usually causes an ______________ in emulsion speed and always causes an ______________ in fog density.

4. Raising the temperature to accelerate development necessitates the use of an increased concentration of bromide as a ______________.

5. The temperature coefficient of development for many emulsion-developer combinations depends upon what level of the photographic material?

6. In the equation:

$$\log t = C - kT$$

fill in the letters t, c, k, and T in the appropriate statements below:

*a.*_____ = time required to develop to a given density or gamma.
*b.*_____ = temperature.
*c.*_____ = constant.
*d.*_____ = constant.

4-3. Controlling Water Quality

Because water comes from an infinite number of sources and contains a wide variety of impurities, which may or may not affect a given process, no standards for quality exist. In the photographic process, although the harmful impurities can be removed by distillation, the use of distilled water might cause softening and reticulation of emulsions. Adding salts might prevent reticulation, but salts might also react unfavorably with the emulsion and with the processing chemistry. Preexamination of the water by chemical analysis is time consuming and costly, and may not uncover harmful impurities. The usual procedure is to use the water in the process and observe and evaluate the results. Thus, if an unwanted reaction occurs, conduct analyses to determine the nature of the impurity, and take the necessary steps to remove it. However, where the process is as critical as in imagery production laboratories, the quality of the water should be established in the beginning. The first condition that should be determined is hardness.

652. List the impurities that may be found in natural waters and state the effects of calcium and magnesium ions in water.

Hardness. Among the impurities found in all natural waters, including rain and snow, are: calcium, magnesium, fluoride, mineral acidity, silica, sodium and potassium salts, hydrogen sulfite, iron, manganese, carbon dioxide, methane, oxygen and nitrogen, chlorine, copper, lead, zinc, turbidity and sediment, pigment, and microbiological growth, algae, and slime.

It is essentially the measure of the calcium (Ca) and magnesium (Mg) present in the water that determines its hardness. "Hard" water is that which contains 100 ppm (parts per million) or more of these elements. Probably the most common water problem is the difference in hardness between surface and underground water sources. Surface waters average approximately 100-ppm hardness, while underground waters average approximately 200-ppm hardness, but this does not give a true indication of the vast range of conditions that exist.

When present in large quantities, calcium (Ca) and magnesium (Mg) may be precipitated in the processing solutions as carbonates, sulfites, phosphates, or borates. These reactions are, to some degree, functions of the pH of the processing solutions and tend to increase as pH increases. Calcium does not precipitate in acid processing solutions. Ca and Mg also build up scale in water pipes, heat exchangers, processing tanks, etc., and in extreme cases, may even deposit onto film or paper during processing. This precipitation may be minimized by adding sequestering agents such as "Calgon" or "Quadrafos" (sodium hexametaphosphate) at the approximate concentration of 0.5 grams/l for water of 100-ppm hardness. However, before using sequestering agents, run tests to insure that they will not adversely affect the process.

Exercises (652):

1. List the impurities that may be found in natural waters.

2. What determines the hardness in water?

3. When present in large quantities in the processing solutions, what happens to the calcium and magnesium ions?

4. What can be done to minimize the precipitation of magnesium and calcium from the processing solution?

653. List the methods for finding the hardness of water, and identify purposes and procedures used with these methods.

Tests for Hardness. There are several methods for finding the hardness of water, including the following:

- Gravimetric analysis (for Ca and Mg).
- Colorimetric titrations.
- Soap test.
- Palmitate titration.
- Soda reagent procedure.

The palmitate and soda reagent tests are seldom used. The soap test and the colorimetric titrations are most popular, but lack the high degree of precision obtained with gravimetric determinations. In the imagery production laboratory, the use of one or the other of the tests given here is generally sufficient to determine hardness.

Soap test. In this method, a standard soap solution specified by the American Public Health Association (APHA) is used. Fill a buret with the soap solution and add, by titrating, to a 50-ml sample of water until a permanent lather forms when the sample is shaken. The lather is considered permanent if it lasts for at least 5 minutes.

Subtract a lather factor of 0.3 ml from the total amount of soap solution used and multiply the remainder by 20. This gives the hardness of the sample expressed in ppm as calcium carbonate.

EDTA determination of total hardness. This analytical procedure employs reagent grade disodium ethylenediamine tetraacetate (EDTA) as a standard volumetric solution in titrating calcium and magnesium ions. A magnesium salt is added to the EDTA solution to insure an easily detectable end point for the titration. The magnesium added to the EDTA is compensated for in the standardization procedure.

EDTA, at the pH involved in this test, strongly reacts with or complexes, calcium and magnesium. At the beginning of the titration, where the calcium and magnesium ions are in excess, the "Eriochrome Black T" indicator has a wine red coloration. When sufficient EDTA is added to complex all of the calcium and magnesium, the indicator sharply changes to pure blue. Once the necessary solutions are prepared, total hardness determinations on water samples can be run very rapidly. The method affords an excellent means of recording variations in water hardness at different sources and perhaps seasonal variations in the water supply.

The reagents required for this determination are prepared as follows:

a. Buffer—dissolve 5.75 grams of ammonium chloride (NH_4Cl) in about 40 ml of distilled water. Add 47 ml of distilled water. Add 47 ml of concentrated ammonium hydroxide solution (NH_4OH) and dilute to 100 ml with distilled water.

b. Indicator—mix 0.25 gram of "Eriochrome Black T" with 2.25 grams of hydroxylamine hydrochloride ($NH_2OH.HCl$) and dissolve in 50 ml of ethyl alcohol.

c. Standard calcium carbonate solution—accurately weigh, on an analytical balance, 1.000 gram of calcium carbonate ($CaCO_3$) and quantitatively transfer to a 1-liter volumetric flask with distilled water. Carefully add concentrated hydrochloric acid (about 3 ml) to the flask until all of the $CaCO_3$ is dissolved. Dilute to exactly 1 liter with distilled water.

d. EDTA solution—accurately weigh, on an analytical balance, 7.8050 grams of EDTA and quantitatively transfer to a 2-liter volumetric flask with distilled water. Accurately weigh 0.100 gram of magnesium chloride ($MgCl_2 \cdot 6H_2O$) and quantitatively transfer to the same flask. Dissolve and dilute to exactly 2 liters with distilled water.

For standardization, volumetrically pipet 25 ml of the $CaCO_3$ solution into a 250-ml "Erlenmeyer" flask. Add 1 ml of buffer and 4 or 5 drops of the indicator solution. Titrate with EDTA solution until indicator just turns from wine red to blue (the end point is abrupt). The standardization factor for the EDTA solution is based on a 100-ml sample. If a different sample size is taken, for very soft or very hard water, multiply the results by the appropriate factor:

$$\frac{250}{\text{ml of EDTA}}$$

Example: If it required 24.00 ml of EDTA to reach the titration end point, the factor is:

$$\frac{250}{24} = 10.42$$

For the analysis procedure perform the following:

(1) Volumetrically pipet 100 ml of the water sample into a 250-ml "Erlenmeyer" flask.

(2) Add 2 ml of buffer and about 6 drops of indicator.

(3) Titrate with EDTA. At the end point the solution should be clear and the color change is from wine red to pure blue.

(4) Calculate for total hardness: ppm ($CaCO_3$) = ml of EDTA × factor. For example, if a 200-ml sample is taken, multiply the results of 0.5. If a 25-ml sample is taken, multiply by 4.

Exercises (653):

1. List the methods for finding the hardness of water.
2. Of the tests listed in exercise 1, which are the most popular in use?
3. In the soap test, how is the hardness of the sample expressed?
4. In the EDTA determination of total hardness, what salt is added to the EDTA solution to insure an easily detectable end point for the titration?
5. What method provides an excellent means of recording variations in water hardness at different sources and seasonal variations?
6. List the reagents that are required for the EDTA determination of total hardness.
7. The standardization factor for the EDTA solution is based on what ml water sample size?
8. When titrating with EDTA solution, what happens to the water sample solution when the end point is reached?

654. Specify the testing procedures and results of testing for chloride and alkalinity in the water supply.

Tests for Other Impurities. Unless your facility employs a graduate chemist, complete analysis for impurities in your water supply may be beyond your ability to perform. However, any well-equipped chemical control laboratory should be able to conduct tests for chloride and for alkalinity. If other tests should be required, they should be made by an outside agency.

Chloride test. To conduct this test, fill a buret with standard silver nitrate solution. Next, take a 50-ml sample of the water to be tested and neutralize it by adding 4 or 5 drops of phenolphthalein indicator plus enough sulfuric acid to make the solution colorless. Then add 5 drops of potassium-chromate indicator, which will turn the solution to a bright yellow. Slowly titrate silver nitrate until 1 drop produces a permanent reddish color. Subtract 0.2 ml from the total amount of silver nitrate used and multiply the remainder by 20. This gives the amount of chloride present expressed in ppm as Cl.

Alkalinity test. The alkalinity titration is done in two steps as follows:

(1) Fill a buret with 0.05–N sulfuric acid. Then add 4 or 5 drops of phenolphtalein indicator to a 50-ml sample of the water to be tested. If the water turns red, add acid from the buret, stirring until the color disappears. Note the reading on the buret.

(2) Add 4 drops of methyl-orange indicator to give a yellow color to the sample. Continue titrating the acid until the color of the sample changes to a reddish orange. Note the total amount of acid used.

The acid used in the first step multiplied by 20 equals the P (phenolphthalein) alkalinity in ppm. The acid used in the second step plus the first step multiplied by 20 equals the M (methyl-orange) alkalinity in ppm. Both figures are expressed in terms of calcium carbonate.

The P and M alkalinity titrations do not indicate specific ions. They measure the several ions contributing to the alkalinity, including carbonate, bicarbonate, hydrate, phosphate, silicate, etc. Titration to the P end point is assumed to determine all of the hydroxide and one-half of the carbonate alkalinity; titration to the M end point is assumed to measure the sum of bicarbonate, carbonate, and hydroxide.

Exercises (654):

1. What standard solution is used to conduct the chloride test?

2. How do you neutralize the water sample in the chloride test?

3. The addition of potassium-chromate indicator does what to the water sample solution?

4. Titrating the water sample with silver nitrate will eventually turn the bright yellow solution to what color?

5. In the alkalinity test, if phenolphthalein is added to the sample size, and the solution turns red, what does that indicate?

6. After you have added acid to the water sample until the red color disappears, the reading multiplied by 20 equals what?

7. Adding methyl-orange indicator after the procedure in exercise 6 will give what color to the water sample?

8. Adding acid to the water sample in exercise 7 until the color of the sample changes to a reddish orange and multiplying the reading by 20 gives what figure?

9. What do the P and M titrations measure?

655. List water treatments that may be available to your facility and identify various processes with the purposes they serve.

Water Treatment. The water supplied by most municipal water systems is treated in some respect. It has probably passed through a system of settling tanks and filters to remove sediment and turbidity. Its hardness, if excessive, may be lowered. Objectionable color may be coagulated with alum and activated carbon and removed in settling tanks. Tastes and odors may be removed or reduced by aeration and activated carbon filters, and microbiologicals undoubtedly are treated by chlorination. Such water is fit for human consumption. However, municipal waters sometimes contain impurities which are detrimental to the photographic process and require additional treatment in your own plant. If the water is too hard, ion-exchange water softeners will provide soft water as long as the ion-exchange resin is properly maintained and regularly regenerated. Filters on your in-plant water lines will help control any turbidity that may exist. Iron and manganese may be controlled with ion-exchange units.

Carbon dioxide, if present, can be controlled by adjusting the pH or by the addition of corrosion inhibitors. Any excess alkalinity can be controlled with ion-exchange dealkalizing or demineralizing units.

There are an infinite number of treatments that may be given, but you must remember that they should only be used if absolutely necessary. If your water supply is compatible with your process, let it alone. If it is not, correct only the condition that is wrong. It is possible to get water too pure or too soft for your process.

Exercises (655):

1. List the additional treatments that may be made available to your facility.

2. What does the ion-exchange water softner provide?

3. What can be done to help control turbidity in the in-plant water lines?

4. How is objectionable color removed or minimized?

4-4. Establishing Replenishment Programs

You have studied principles and procedures of quantitative analysis. This study, plus the application of statistical analysis, will enable you to formulate a replenishment program. Do not assume that the information you have studied will be sufficient in all cases. We have covered basic principles that you must enlarge upon during practical application.

656. State how to conduct replenishment calculations.

To conduct your replenishment calculations, something similar to the following program is usually followed:

a. Completely analyze a fresh mix to determine the analyzed quantity of components present in the mix.

b. Run a sensitometric test on the fresh mix and decide what limits you must maintain.

c. Run an exhaustion test on your solution by processing controlled quantities of specially prepared film until you reach the exhaustion point. This point is based on the sensitometric limits that you can tolerate.

d. Analyze the solution at various times during the exhaustion run as well as at the end of the run.

e. On the basis of chemicals lost and gained, calculate a replenisher formula.

f. Prepare the replenisher for use and start a processing run with fresh mixes. Observe this operation carefully; employ sensitometric tests and, if necessary, chemical analyses.

g. If the replenisher is satisfactory it can be used. If it is not, recalculate and retest.

The above approach allows you to calculate replenishment for any developer. Basically, you determine what changes occur as a result of a measured amount of use, and compute what additions you must make to the developer to correct for those changes. This requires that you keep complete records of the entire process to enable you to set up an acceptable program and to insure that the program continues to be acceptable.

Exercises (656):

1. When conducting a replenishment program, why do you completely analyze a fresh mix?

2. How do you set up the limits that you must maintain?

3. In the exhaustion test, on what criteria is the exhaustion point based?

4. How do you calculate a replenisher formula?

657. State why there is a need for developer replenishment.

Reasons for Developer Replenishment. Uniformity of development is, in a large measure, dependent upon the activity of the developer. As development progresses, two important changes occur in the development solution: (1) certain components become exhausted, and (2) bromide ions are released into the solution. If the action of the developer is to be uniform, some measures must be taken to counteract or compensate for these changes. In a word, "replenishment"—it's necessary.

When a developer is in continuous use for a period of time and has reached the point of exhaustion, the most noticeable change is that it has lost a number of things. First, the quantity of solution is less, due partly to evaporation and chiefly to carryout. Second, its pH is lowered; and its alkali, developing agents, and preservative are reduced in strength and quantity. Also, the exhausted solution contains an increased amount of bromide ions plus waste products, which include the redox products, some gelatin, sensitizing dyes, antihalation dyes, free silver, etc. Third, it may contain foreign matter; i.e., dust, dirt, etc., which could be removed by filtration.

The emulsion coating on sensitized film material contains bromide ions which are released into the developer solution during processing. This action results in an excessive bromide concentration called bromide buildup, which causes an undesirable restraining action and results in a loss of shadow density and increased contrast. Since the excess Br^- ions slow down the action of the developer at an ever-increasing rate, the first consideration in designing a replenisher is to control the bromide buildup. Then your attention must be turned to replacing those components which are consumed.

With use, a nonreplenished developer solution becomes lower in activity as a result of: (1) depletion of the developing agent or agents, and (2) restraining effect of byproducts of the process, such as halides and developing agent oxidation products. Not much can be done to compensate for the presence of the developing byproducts except to minimize their effect through dilution. However, the amount of dilution that can be given is limited by the amount necessary for the control of the Br^- ions. On the other hand, the components of the developer can be replaced at a rate which will maintain the proportional quantities present in a fresh developer.

Exercises (657):

1. As development progresses, what two important changes occur in the developing solution?

2. If the action of the developer is to be uniform, what measures must be taken to counteract or compensate for these changes?

3. What are the changes caused by the exhaustion in a developer?

4. What are the results of the undesirable action of the bromide buildup?

5. What is the first consideration in designing a replenisher?

6. What causes a nonreplenished developer solution to become lower in activity?

658. Specify the basis and factors in a replenishment program and identify the replenishment preparation steps.

Preparation of a Replenisher. Since the function of a replenisher is to provide a means for controlling the developing process, your particular replenishment program must be built around your process requirement. That is, you must base your program on statistical evaluations of your process. Once you have determined what your standards should be, the next step is to establish a replenishment program, using a formula designed for your situation.

You must also consider these factors: (1) the standards set for your certified solutions must be met; (2) if solutions have been modified, the replenisher must be calculated for the modified formula; and (3) if additions have been made to an existing developer, you must decide whether or not the additions constitute a modification to be continued. Otherwise, your formula will not suit your solution. When you thoroughly understand your requirements, you are ready to design your formula.

The first step in compounding a replenisher formula is to take a measured amount of the developer in question, analyze it, exhaust it, measure it for volume, and analyze it again for content. This will provide the approximate information needed to make the replenisher. Water is added to dilute the bromide and to provide the vehicle for the alkali, developing agents, and preservatives which will replace those constituents exhausted from the developer. In some of the more energetic developers, the Br^- buildup is so great that mere dilution will not suffice, and sometimes caustic alkalis are added in an effort to overcome this. Figure 4-2 illustrates the analysis of a hypothetical developer which is subjected to an exhaustion test.

Exercises (658):

1. Your replenishment program is based on what type of evaluations of your process?

2. What factors do you consider when you establish a replenisher program?

3. What is the first step in compounding a replenisher formula?

4. What is the purpose of adding water to the replenisher formula?

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TANK ANALYSES, grams/liter

	FRESH DEVELOPER MIXED AT, OR AIM	FRESH DEVELOPER	(1200 ft) 30 min	(2400 ft) 1 hr	(4800 ft) 2 hr
Hydroquinone	5.00	4.92	4.67	4.40	3.95
"Metol".	4.00	3.96	3.64	3.40	2.76
Sodium sulfite, anhydrous*	50.0	49.6	49.0	48.5	47.4
Sodium **bromide . . .	1.50	1.48	1.73	2.02	2.55
Sodium carbonate, monohydrate. . . .	40.0	39.6	38.9	38.4	37.2
pH at 70 F	10.20	10.18	10.15	10.10	10.02

*All further references to sulfite in this table pertain to the anhydrous salt.

**Potassium bromide may be used in place of sodium bromide.

Average loss of hydroquinone per min (or per 40 ft)

$$= \frac{\frac{4.92 - 4.67}{30} + \frac{4.92 - 4.40}{60} + \frac{4.92 - 3.95}{120}}{3}$$

$$= 0.00836 \text{ gram}$$

Average gain in sodium bromide per min (40 ft)

$$= \frac{\frac{1.73 - 1.48}{30} + \frac{2.02 - 1.48}{60} + \frac{2.55 - 1.48}{120}}{3}$$

$$= 0.00875 \text{ grams}$$

The following are calculated in a similar manner;

Average loss of "Metol" per minute (40 ft.) = 0.0100 gram

Average loss of sodium sulfite per minute (40 ft) = 0.0189 gram

Average loss of sodium carbonate, monohydrate per minute (40ft) = 0.0211 gram

Average loss in pH*** per minute (40 ft.) = 0.00122

***pH is not a linear relationship so that the pH loss per minute (or per 40 ft of film) must be regarded as only a useful approximation.

Figure 4-2. Developer exhaustion test.

659. State the method used to calculate a basic replenisher formula for batch processing.

Calculating the Formula. A basic replenisher formula is intended to be used concurrently with processing. Therefore, it is obvious that a replenisher formula, no matter how accurately compounded, will require some adjustment as development progresses. The following procedure outlines a method for calculating a replenisher formula for batch processing; however, the same principles can be applied to machine processing.

The first step is to determine the criterion for exhaustion. Exhaustion does not imply total exhaustion, but only that point below which the result is unacceptable. You might use gamma, D_{max}, and/or Δ D (density difference) between two selected points as your criterion. Next, analyze the developer to be used to determine the quantity of each component. Do not base your calculations on the quantities that went into the developer because your analysis may show some discrepancy. Then process film in a given quantity of developer until exhaustion is reached. Next, measure the volume of the solution remaining to determine loss by evaporation and carryout and perform an analysis to ascertain the change in the quantities of the components. Finally, determine the amount of water and chemicals required to maintain constant developer strength.

The following example illustrates a typical procedure. Assume that after 50 batches of 12 sheets each were processed in 4,000 ml of a developer solution to reach the exhaustion point, 3,600 ml of solution remained. The chemical analysis you performed showed the following comparative quantities in grams/liter:

Component	*Original Component Solution*	*Exhausted Solution*	*Difference*
Metol	1.5	0.8	−0.7
Sodium sulfite	45.0	41.5	−4.5
Hydroquinone	3.0	2.1	−0.9
Sodium carbonate (Anh)	6.0	4.6	−1.4
Potassium bromide	0.86	2.04	+1.18

If 3.60 liters of the exhausted solution contain 2.04 g/l KBr, what volume of water must be added to dilute it to the original 0.86 g/l of KBr? Calculations show that:

$$\frac{0.86\ \text{grams}}{1\ \text{liter}} = \frac{2.04\ \text{grams}}{x\ \text{liters}} = 2.37\ \text{liters}$$

Therefore, every liter of solution remaining must be increased to 2.37 liters by adding 1.37 liters of water. This will dilute the KBr to the original 0.86 g/l.

This volume of water takes care of the bromide, but now the consumed ingredients must be replaced. The replenisher must contain the following quantities (g/l):

Metol	1.5 + 0.7 = 2.2
Sulfite	45.0 + 4.5 = 49.5
HQ	3.0 + 0.9 = 3.9
Sodium carbonate (Anh)	6.0 + 1.4 = 7.4

The volume of replenisher that must be added to the same kind of developer to process the same quantity of film is as follows:

$$3.60\ \text{liter} \times 1.37 = 4.9\ \text{liters}$$

As previously stated, the same principles apply to calculating replenisher formulas for machine processing. The difference is that the processing of film is continuous instead of in batches.

Exercises (659):

1. State the first step to consider when calculating a replenisher formula, listing several of the approaches available for this step.

660. Identify selected steps in the use, modification, and monitoring of replenishers with their occurrences, purposes, and control guides.

Using the Replenisher. Since the components of a developer begin to change as soon as the first film is placed in the solution, it follows that replenishment should begin at that time and be carried on simultaneously with development. This is possible and should be done in machine processing. However, it is not feasible with tray or tank development, and replenishment should be accomplished by using the topping off method.

Processing machines should be equipped so that replenisher can be introduced into the tanks during processing. In some cases, metered amounts of solution can pass from booster bottles through flowmeters into the tanks. An excellent method is to circulate the developer through filters to a separate conditioning tank. This tank is equipped with heat exchangers for temperature control and flowmeters for introducing the replenisher into the developer. Some processing machines are equipped with ion exchange columns in the circulatory system to remove the Br^- ions as they are released. However, this system requires constant control and for that reason is not widely used.

Corrections and modifications. Based on sensitometric evaluation and chemical analysis, replenishers are often altered to produce a desired effect or to correct an undesirable one. The conditions of actual practice may differ from the conditions under which the replenisher was formulated, and if this is so, the results will be other than expected. If the alkalinity varies, the rate of development will vary; therefore, frequent tests for alkalinity must be made. Alkalinity problems may occur for several reasons, but one of the most common occurs when strong alkalis such as sodium hydroxide are used to overcome excessive Br^- ion buildup. Since sodium hydroxide does not have a high buffering capacity, the pH of the solution may fluctuate, and the process must be monitored frequently. When the alkali content of a developer tends to drop, the addition of greater amounts may solve the problem. But if it tends to increase, dilution will not help because all of the other components will also be diluted. In some laboratories acid has been used to neutralize a portion of the excess alkalinity, but this practice is difficult to monitor and control. It is far more desirable to reconstruct your replenisher formula than to attempt to modify it in the course of the processing run.

Monitoring the process. The use of replenishers, while important and necessary to uniform processing, can only perform efficiently for a limited time. It is not possible to replace chemicals exactly as they are used, nor is it possible to control the Br^- buildup accurately. Further, filters cannot remove all of the waste materials or redox products, and eventually the developer cannot deliver the desired results; hence the necessity for control. Control charts must be kept on the entire operation. Using sensitometric tests, provide the information needed. Your control charts will show you when your process is not producing results within your predetermined limits, and you can either alter the replenishment or discard the solutions, whichever is indicated.

Remember, replenishment is for the purpose of maintaining uniform quality over a longer period of time before it becomes necessary to change solutions. It is unwise to try to use a solution beyond its useful life; therefore, let us repeat—you must have sensitometric and statistical control.

Exercises (660):

1. In machine processing, at what period in time should the replenishment begin?

2. What is the reason for running frequent alkalinity tests?

3. What will show you whether your process is producing or not producing results within your predetermined limits?

661. State the reason for silver recovery from a fixing bath, the most useful method of recovery, and the method for measuring the amount of silver in a fixing bath.

Replenishment of Fixing Baths. From time to time the subject of archival quality comes up. One of the important factors is washing. However, before you can have efficient washing, you must have efficient fixation if archival quality is to be obtained.

During processing, silver gradually increases in the fixing bath. As the silver builds up, the efficiency of the fixing bath decreases unless some form of silver recovery is accomplished. For a lab with limited production, it is usually cheaper to discard the fixing bath. High production rates, however, make the recovery of silver monetarily feasible. Not only can the silver be saved, but an added saving is accomplished by reconstituting the fixing bath for further use.

Certification of a fixing bath includes a specific gravity test, pH test, and total acidity test. A small piece of film is often immersed to validate clearing action. One major problem exists, however. That is, when is the bath exhausted? Without analysis of the bath to determine its stability, the operator must make a decision, based on empirical knowledge, as to when the solution is to be discarded. Such a decision usually comes when exhaustion seems apparent. This method hardly befits an imagery production operation.

As an example of rigid control and standardization, let us consider a typical study in this area which was pegged to the operation of an HTA-2 processing machine. The following fixing bath formula was decided on:

a. Water—about 32 gallons.
b. Kodak Rapid Fix (solution A)—11¼ gallons.
c. Kodak Hardener (solution B)—135 ounces.
d. Water to make 65 gallons.

After production runs were started, samples of the fixing bath were collected at predetermined intervals (at about every 1,000 square feet of processed material) and analyzed to determine the concentration of the components, specific gravity, total acidity, and silver deposited in the solution. Component levels and other standards established for use of the solution were as follows:

a. Sulfite—8.0 g/l ± 2.0 g/l.
b. Ammonium thiosulfate—95.0 g/l ± 10.0 g/l.
c. Specific gravity—1.06 ± 0.02.
d. Total acidity—pH 4.5 ± pH 1.0.
e. Silver—not to exceed 5.0 g/l.

NOTE: Tentative safe level for use when archival quality is required.

All analysis data were graphed and averaged to illustrate existing conditions for a 5-month period of use. The results showed that the fixing bath remained in control until about 5,000 square feet of film had been processed. At this time a definite drop of all components was noted and a silver buildup to 5 g/l was recorded. At this point, it was decided that an adequate representation of sampling was accomplished to properly establish the point of exhaustion with replenishment.

It was determined that two approaches could be pursued to extend the life of the fixing bath: (1) use of a replenisher, or (2) use of a replenisher and silver reclaiming system. With the first system the tank life was extended to 7,000 square feet. Cost of the solution per square foot remained the same. Added benefits of this method were increased archival quality and reduced processor shutdown time. The replenisher formula used at a rate of 200 cc per minute was prepared as follows:

a. Water—about 25 gallons.
b. Kodak Rapid Fix (solution A)—8¾ gallons.
c. Kodak Hardener (solution B)—105 ounces.
d. Water to make 50 gallons.

With the application of replenishment, quantitative chemical analyses over 7 months showed that standards for use were maintained up to 8,000 square feet of film. The limiting factor in achieving greater extended tank life was a silver buildup to 5 g/l. Thus, a satisfactory replenishment system must include the removal of silver from the solution.

Silver is recovered from a fixing bath by causing it to precipitate out. This can be done chemically, but the bath must be exhausted and cannot be reused after silver recovery. The most useful method precipitates the silver by electrolysis, and the bath may be subsequently reused. If desired, the bath can be used while part of it is in the silver recovery system. One silver recovery method passes an electrical current between electrodes immersed in the fixing bath. Another method utilizes a device consisting of an arrangement of separate zinc and copper screens or plates placed in the fixing bath.

Another type of silver recovery uses a direct current rectifier and a plating tank containing carbon anodes and stainless steel cathode plates. A pump pulls fixer from the storage or recirculation vat and forces the fixer through a series of pipes in the bottom of the recovery tank and up past the plates. It then flows out through an overflow and back to the vat. When plating thickness is sufficient, the steel plates are removed and the silver is taken off. After silver removal, the plates are ready for replating.

You will recall from your previous studies that the amount of silver (grams per liter) in a fixing bath can be determined by using an argentometer. This is a specialized photometer for determining silver content of a fixing bath. The instrument is used to check fixer samples (taken from the processing system). In our previous example (5 g/l of silver maximum), you would take samples from time to time to insure that the amount of silver is within tolerances—something less than the 5 g/l. Just as with other samples, the sample of fixing bath is taken from a specific and representative place in the machine. Subsequent samples are also taken from the same place.

Exercises (661):

1. Why is the recovery of silver from a fixing bath important?

2. What is the most useful method to recover silver from the fixing bath?

3. How can you determine the amount of silver (grams per liter) in a fixing bath?

662. State the hazards and problems encountered in bleach rejuvenation.

Rejuvenation of Bleach. If the bleach is to be rejuvenated by the addition of bromine, it is recommended that the ferrocyanide level be maintained between 2.5 and 5 grams per liter by additions of bromine at the necessary frequency. Rejuvenation should be conducted at intervals of every 15 to 20 feet of 35-mm film per liter of total bleach solution.

If the first procedure is used, the number of milliliters of bromine required is calculated as follows:

ml • Br_2 = Volume in liters of bleach system x [ml • Ce $(SO_4)_2$ x N of $Ce(SO_4)_2$ x 0.512 - 0.0696]

while, if the alternate method is followed,

ml • Br_2 = Volume in liters of bleach system x [ml • KMn O_4 x N of KMn O_4 x 1.28 - 0.174] (30)

Bromine is measured out according to the above computation. Technical grade bromine is used, not bromine water. It is measured off into a graduate while working under the hood. A layer of water is added over the bromine to reduce fuming. The bromine is then added to the bleach. Operators should wear rubber gloves and goggles.

The addition of the bromine should be made in a reserve circulation tank fitted with powerful stirring apparatus located as low as possible in the bottom of the tank. The tank should be provided with a tightly fitted cover. The bromine will lie at the bottom of the tank unless vigorous and complete stirring is given and in case an excess amount is used. If uncombined bromine is accidentally circulated into the machine tank, bleaching of the dye image is likely to occur. If it is found impractical to rejuvenate during idle periods, the circulation tank should be fitted with valves to bypass it and enable it to be used during regular operation of the machine. The tank should be a rubber-coated or vitreous ware unit. Its fittings should be of hard rubber. In addition to restoring the ferricyanide, the bromine also replaces the very important bromide as one product of the reaction.

Procedure Where Bromination Cannot Be Conducted. The concentrations of ferricyanide and bromide may be maintained at the desired level and the ferrocyanide at the proper dilution by additions of the bleach replenisher. If this method of bleach rejuvenation must be used, the initial bleach mix should be "conditioned" by including 5 grams per liter of potassium ferrocyanide. When the ferrocyanide concentration rises to about 7.5 grams per liter, the replenisher should be added to restore the 5 grams per liter concentration. The amount necessary to be added is calculated from the following formula:

Liters of replenisher required = liter volume of tank—*liter volume of tank* where E is the measured ferrocyanide concentration in grams per liter divided by 5.

Before adding the replenisher, drain and discard an equal volume of used bleach from the machine tank.

Exercises (662):

1. How often should the bleach be rejuvenated?

2. What precaution should the operator take when measuring Bromine?

3. What will probably cause the dye image to be bleached out?

4. How should the initial bleach be treated when bromination cannot be conducted?

5. How should the replenisher be added?

Answers for Exercises

CHAPTER 1

Reference:

600 − 1. A quick check on the specific gravity of the newly prepared batch of solution will tell you whether or not the solution merits further testing. By comparing the specific gravity reading with the standard specific gravity for this same solution, you have a rough indication that all the constituents were (or were not) added and that the relative amounts of water and combined solutes are (or are not) correct.

600 − 2. The specific gravity for a particular solution should stay within an upper limit and a lower limit. That is, through the maintenance of records and through the inspection of the products produced, you can accurately determine what the specific gravity of a given solution should be. Variations beyond the upper limit or beneath the lower limit is indicative of a substandard solution.

600 − 3. You can reasonably assume that the solution was prepared accurately enough to justify further testing. (The specific gravity test is normally the first test made on a newly prepared batch of solution.)

601 − 1. Given:

Empty bottle	= 65.3 gm
Bottle filled with H_2O	= 115.1 gm
Bottle filled with salt solution	= 120.7 gm

Solution:

120.7 gm − 65.3 gm − 55.4 gm weight of salt solution

115.1 gm − 65.3 gm = 49.8 gm weight of equal volume of water

$$\frac{55.4\text{ gm}}{49.8\text{ gm}} = 1.11 \text{ Sp. gr. of salt solution}$$

602 − 1. By preparing standard mixes at 70°F.

602 − 2.
- a. Fill the hydrometer cylinder with sample solution.
- b. Adjust temperature of the sample to read 70°F. ±1°.
- c. Dry the hydrometer thoroughly and carefully, lower it into the sample.
- d. Read hydrometer at top of the meniscus.

603 − 1.
- a. Cleanliness and accuracy are essential in chemical weighing and mixing. Avoid spilling chemicals on balance or over work area to prevent chemical corrosion on balance and possible contamination of other chemicals in the work area. Chemicals inadvertently spilled should be cleaned up immediately.
- b. Avoid handling class S weights. Through corrosion, perspiration and oil on your hands can change the true weight of these small weights and thereby result in inaccurate chemical measurements. Handle small weights with a pair of tweezers or forceps. Use the least number of weights possible when weighing chemicals. When counterbalancing a measure of chemical, try the larger weights first and then the smaller weights in systematic order.

603 − 2. To assure that contamination of one chemical with another is prevented.

603 − 3. You are less likely to omit any chemical ingredients.

603 − 4. In an area where the temperature remains constant and out of direct sunlight and air currents. Chemicals are weighed at room temperature.

603 − 5. Take precautions to prevent damaging the agate knife edges and pans. Raise the beam and pan supports. Leave nothing on the pans. Make sure the case door enclosing the balance is closed.

603 − 6. Placing chemicals directly on the pans will cause corrosion.

603 − 7. The caustic chemical will chemically react with the aluminum pan causing corrosion.

603 − 8. Place the larger weights in the center of the pans.

604 − 1.

Left	*Right*	*Average*	*Rest*
	+5.7		
−6.2	+5.6	−6.1	
−6.0	+5.5	+5.6	
2)−12.2	3)16.8	2)−0.5	
−6.1	5.6	−0.25	−0.25

604 − 2.

Left	*Right*	*Average*	*Rest*
8.5			
8.3	13.3	8.3	
8.1	13.1	13.2	
3)24.9	2)26.4	2)21.5	
8.3	13.2	10.75	10.75

605 − 1. Left; right; balance.

605 − 2. Zero.

605 − 3. Rest.

605 − 4. Sensitivity.

605 − 5. Sensibility.

606 − 1. Using the formula in the exercise and substituting values, we have:

$$\frac{0.6 - (-02)}{2} = \frac{.8}{2} = 0.40 \text{ milligrams}$$

The plus sign indicates that the left pan is heavier and 0.40 milligrams of sulfate cerate must be removed. If sulfate cerate is being weighed in the amount of 27.413 g, the error correction is 0.00040 and the total amount of sulfate cerate is 27.41340.

607 − 1. There is a need for a correction factor to take into consideration the buoyancy effect.

607 − 2. Gravity, buoyancy of air, surface moisture, and static electricity.

607 − 3. They collect an electrical charge and in this state can attract or repel other objects which could cause a change in apparent weight.

607 − 4. An atmosphere low in relative humidity.

608 − 1. The substitution-type balance uses remotely controlled weights selected in increments of 0.1 gram, 1 gram, or 10 grams. The precision reading dial registers in thousandths of a gram and a vernier scale can read to one ten-thousandth of a gram.

609 − 1. The laboratory pH meter is a portable, battery-powered, precision meter having sufficient accuracy for most applications in photoprocessing laboratories.

609 − 2. This model operates within the pH of 0 to 13 pH and within the millivolt range of 0 to ±1,300 mv.

609 − 3. The safety slide automatically turns the instrument off as the cover closes.

609 − 4. This meter is a precision digital-display instrument designed for accurate measurements of pH and electrode potentials in a wide range of industrial and biomedical applications and in research. The digital display of the pHI 71 pH meter reads to 0.001 pH and 0.1 mV. When the instrument is used with an ATC (Automatic Temperature Compensator) probe, digital display also reads temperature to 0.1°C.

610 − 1. You should avoid dropping or jarring the instrument since sharp blows may damage meters and cause electronic failures.

610 − 2. Maintaining a high input impedance and proper grounding.

610 − 3. An inner electrode contaminated by alcohol, acetone, or similar substance.

610 − 4. An air bubble, an insufficient KCl solution, a dry liquid junction, or faulty contacts.

610 − 5. Storing the instruments over long periods of time with an empty KCl reservoir.

610 − 6. Fill the KCl reservoir and replace the sleeve over the filler hole. Place the rubber cap over the liquid junction tip in order to prevent the drying out of the fiber and interrupting the liquid junction.

610 – 7. The pH meter must be aligned to a standard reference.

611 – 1. When selecting a water still, you should determine the requirements of the facility. Select a distilling rate fast enough to allow for future requirements. The choice between an electric, steam or gas heated still usually depends on the facilities available at your facility; however, electrically heated stills are generally preferred in most imagery production laboratories because they offer great convenience, are easily installed, switch controlled, and have no open flame.

611 – 2. The hard water bleeder valve provides an adjustable outlet that continually bleeds boiling water waste. The automatic protective low-water cutoff automatically shuts off the electric current if the water level falls below proper operating level.

612 – 1. First, silver is a precious metal in relatively short supply and requires conservation; secondly, silver recovery increases the efficiency of the fixing bath chemicals; and thirdly, silver recovery is often profitable.

612 – 2. Only in the electrolytic method of recovery.

612 – 3. Two electrodes (a cathode and an anode) are placed into a tank containing the silver-bearing hypo. An electric current is passed between these electrodes causing the silver to plate out on the cathode. The amount of current must be carefully determined.

612 – 4. Whether sodium or ammonium hypo is used in bath, on the acidity of the bath, and on the silver concentration and the sulfite concentration in the solution.

612 – 5. This method requires that used hypo solution be brought into contact with a metal surface. The metallic material used is often steel wool. The discarded hypo is collected in a tank, then flowed at the rate of 2 gallons per minute through two tanks in series. Silver in the hypo solution collects on the steel wool. After the collection process is complete, the steel wool is removed from the tank and dried.

612 – 6. Due to the change in chemistry caused by the immersion of the metallic material and the addition of glacity acetic acid.

612 – 7. The used hypo is poured into a non-metalic tank. One ounce of sodium hydroxide solution is added for each gallon of hypo. The sodium hydroxide solution is prepared by dissolving 2 pounds of sodium hydroxide in 1 gallon of cold water. The fixing bath is stirred thoroughly while the sodium hydroxide solution is being added. After stirring is completed, the used fixing bath is tested for alkalinity by using Eastman Kodak Testing Solution A. Additional sodium hydroxide solution is added until the tests turns blue. This indicates that the solution is alkalized. At this point 1 additional ounce of sodium hydroxide for every 5 gallons of waste fixing bath must be added. Now dissolve 2 pounds of sodium sulfide in 1 gallon of water. While stirring, add 1 ounce of the sulfide solution for each gallon of used fixing bath. The above mixture should be allowed to stand for about 30 minutes or until it is clear. To test for complete silver precipitation, dip out about 8 ounces of the clear solution and add sodium sulfide. Keep adding sulfide until all the silver is precipitated. Let the mixture settle for 8 to 12 hours and then drain off and discard the clear solution. Then dry the sludge by some appropriate means.

612 – 8. (1) Add the sodium hydroxide very slowly to the surface of the water to avoid any spattering. Always use cold water when preparing the sodium hydroxide solution. The use of hot water could cause the solution to boil with almost explosive violence. Sodium hydroxide (lye) can cause serious burns.

(2) Keep the sulfide solution away from sensitized materials since the fumes will fog films and papers.

612 – 9. The actual amount is dependent upon the relationship of the flow rate of the used fixer and the volume of steel wool suspended in the tank.

CHAPTER 2

613 – 1. The American National Standards Institute (ANSI).

613 – 2. The ANSI publishes a series of standards covering all the chemicals used in photographic processes.

613 – 3. Specifications that establish the degree of purity and state limiting concentrations for potentially harmful impurities that may be present.

613 – 4. Photo grade.

613 – 5. The quality designations most often used are:
- a. Primary standard.
- b. Reagent grade or ACS.
- c. Chemically pure or C.P.
- d. National formulary or N.F.
- e. Purified.
- f. Technical.

613 – 6. They are found to be within the quality range of U.S.P., N.F., and purified grades.

613 – 7. First, obtain the ANSI specifications for the particular chemical in question and perform laboratory tests as given in the ANSI specs. Chemicals failing to meet the given purity limits should not be used in preparing the photographic solutions.

614 – 1. The preparation of solutions from imagery production differs from ordinary chem-mix procedures only in the amount of care and cleanliness required. Imagery production requirements are more critical and must be held to closer tolerances. Rigid controls must be maintained over the chem-mix function.

615 – 1. The chem-mix section accomplishes this activity by routing the mixed and certified solutions through a system of flow raters (or flowmeters) and pipes to the processing machines.

615 – 2. The chem-mix crew must be informed as to the processor(s) being used, the solutions required, the replenishment rate to be established, the duration of the processing run, and the exact shutdown time.

615 – 3. It must be resistant to chemical reaction.

615 – 4. Glass, certain plastics, hard rubber, and stainless steel.

615 – 5. Stainless steel. Because of its strength and durability, the ease with which it can be maintained, and its high resistance to chemical reaction.

615 – 6. By the use of an on-center, propeller-type agitator which produces a strong downward thrust to the bottom.

615 – 7. Lids, often with clamps to hold them in place, and are sometimes pressurized with nitrogen to exclude air.

615 – 8. By the actual production of the photographic image by deterioration and waste through mishandling and by aerial oxidation.

615 – 9. Have the exposed surface as small as possible in relation to the solution volume.

615 – 10. Clean stainless steel tanks frequently—at least once a week. Flush tanks with clean, demineralized water and rub out stubborn spots with a wet cloth. Never use steel wool or bronze scouring pads on stainless steel. Contact with dissimilar metals tends to induce corrosion. Avoid using any substance that will scratch or abrade the surface.

616 – 1. Control of the photographic process by using chemical concentrations of solutions that are maintained at standard chemical levels.

616 – 2. Centrifuge the samples before taking an aliquot.

617 – 1.
- a. Dipstick (film strip holder).
- b. Dip tank or sensitometric processor.
- c. Sensitometer.
- d. Densitometer (preferably automatic recording).

617 – 2. The agitation system should include gaseous turbulation (burst or continuous), oscillating vanes, or a combination of the two.

617 – 3. A sample of the newly mixed developer.

617 – 4. Call for a retest. If the retest is beyond limits, check exposure as well as origin of film stock used.

618 – 1. Ordinarily, determining the pH, the total alkalinity, and the specific gravity will suffice.

618 – 2. The effective concentrations of hydrogen and hydroxyl ions.

618 – 3. In order to measure this potential with pH meter, a constant potential reference (calomel) electrode is used to complete the circuit.

618 – 4. Temperature.

618 – 5. 0.10 units.

619 – 1. In a water bath within ±1°F. of the appropriate temperature.

619 – 2. Any glass electrode.

619 – 3. New electrodes should be soaked 4 hours in distilled water, immersed for 30 seconds in 3 N hydrochoric acid, rinsed off in

distilled water, and then soaked for 12 to 16 hours in potassium borate buffer.

619 – 4. Remove the electrode from the assembly, immerse it in a solution of 3 N hydrochloric acid for 30 seconds, rinse in running water, and soak in potassium borate buffer for 16 hours.

619 – 5. In a potassium borate buffer.

620 – 1. By means of a primary standard buffer (potassium acid phthalate or borax) of known pH and cross-checked by a second buffer (borax or calcium chloride—calcium hydroxide or known pH).

620 – 2. Lower the electrode assembly into a beaker containing the appropriate buffer while it remains in the water bath.

620 – 3. Replace the faulty electrode assembly and reject all results obtained since the preceding satisfactory cross-check. Repeat the standardization and electrode cross-check procedures with the new assembly.

621 – 1.
- a. Lower electrode assembly into a beaker of sample while it remains in the water bath.
- b. Set the timer for 2 minutes and the pH scale dial at the appropriate pH of the sample.
- c. After 1½ minutes, adjust knobs 1 and 2 alternately until the needle reads zero for both positions 1 and 2.
- d. Lock down the pushbutton.
- e. At the end of 2 minutes, adjust the needle to zero with the pH scale dial; then release the pushbutton and record pH.
- f. Raise and rinse electrode assembly with distilled water. Place in potassium borate buffer in water bath or in the next sample to be tested.

622 – 1.
- a. Repeat the cross-check after the fourth sample measurement and place electrode in potassium borate buffer, or in the appropriate standard buffer if more determinations are to be made.
- b. Repeat the cross-check after the fourth sample measurement and place electrode in potassium borate buffer, or in the appropriate standard buffer if more determinations are to be made.

622 – 2. Yes. No more than 15 minutes should elapse between any standardization and the final cross-check.

623 – 1.
- a. Repeat standardization of pH meter.
- b. Repeat cross-check.
- c. Repeat steps for each sample (no more than four).
- d. Repeat cross-check after fourth sample measurement and place electrodes in potassium borate buffer in water bath.
- e. Using the procedures for multiple samples, determine pH for every batch of solution mixed and take an average value.
- f. Check this value against the standard pH of the solution.
- g. Enter value in appropriate place in your certification sheet.

623 – 2. If the pH is out of standard, this is cause for further investigation.

624 – 1. The milliliters of 0.1000 N sulfuric acid required to titrate a specified volume of processing solution to pH 4.3.

624 – 2. Because most salts derived from weak acids show an inflection point in their titration curves near pH 4.3.

624 – 3. Because it has an abrupt color change near pH 4.3.

624 – 4. The E–O–X indicator gives a sharper color change under fluorescent illumination.

624 – 5. Potentiometrically.

624 – 6. Incorrect amounts of inorganic constituents and certain of the organic constituents.

624 – 7. To a visual end point.

624 – 8. The amount of titrant in milliliters used in the titration is by definition the total alkalinity for a specific sample size of the developer solution.

624 – 9. Check your findings against the standard and record these values in the appropriate spaces on your certification sheet.

625 – 1. Above 4 and below 6.

625 – 2. The pH is usually held to a range of from about 3 to 4.

625 – 3. Emulsion damage, washing out byproducts, staining, and sludge.

625 – 4. The concentration of the potassium alum and the pH of the solution.

625 – 5. Little, if any, hardening action takes place.

626 – 1. Using one liter of processing solution, the numerical value of total acidity is found by summing the amounts of alkali needed to bring each constituent of the solution to pH 8.7.

626 – 2. Total acidity is defined as the milliliters of 0.1000–N sodium hydroxide needed to titrate a given volume of fixing bath solution to a pH of 8.7.

626 – 3. One indication that your fixing bath is deteriorating is the lowering of the pH value of the solution.

626 – 4. In seasoned tanks and in fixing baths containing potassium alum, the color change is often obscured or is too gradual for visual detection.

626 – 5. The sample size is chosen so that the volume of sodium hydroxide consumed falls between 25 and 45 ml.

627 – 1. The argentometer.

627 – 2. A light source, a transparent cell to contain the sample to be tested, a photocell, and a microammeter scaled in grams-of-silver-per-liter.

627 – 3. The light to the photocell is attenuated in proportion to the optical density of the discoloration of the sample.

CHAPTER 3

628 – 1. If it agrees with the known value.

629 – 1. Precision is the measure of a spread in the range of a number of results usually expressed as the deviation from mean or average value.

629 – 2. "A" had poor precision and poor accuracy, "B" had good precision but poor accuracy, "C" had good precision and good accuracy, and "D" had poor precision but good accuracy merely through chance, not from accurate work.

630 – 1. To the decimal place indicated by the preparation formula. Three decimal paces means an accuracy of 1/1000 gram (0.001), two decinal places means an accuracy of 1/100 gram (0.01).

630 – 2. If the weight of tie chemical is specified in grams to two or more digits to theright of the decimal point, use the analytical balance and class S weights.

631 – 1. A detergent soluton, sulfuric dichromate solution, and acid-alcohol.

631 – 2. Naccanol solution

631 – 3. A "dichromatic" solution, consisting of sodium or potassium dichromate in concentrated sulfuric acid.

631 – 4. Acid-alcohol soluton.

631 – 5. Wear rubber gloves and goggles and observe the safety precautions for handling concentrated acids. If acid is spilled on the skin or clothing or splashed into the eyes, flush the affected parts with a large amount of water. Secure competent medical treatment immediately.

632 – 1. 20°C. (68°F.).

632 – 2. Its volume increases and the concentration of chemicals decreases.

633 – 1. The top of the meniscus is read when determining specific gravity because the hydrometer is calibrated on that basis.

633 – 2. It is important that your line of vision be in the same horizontal plane as the bottom of the meniscus.

634 – 1. Solvent; solutes.

634 – 2. Percentage, molar, and normal.

634 – 3. You could use the crisscross method.

634 – 4. Water; alcohol.

634 – 5. 90.

634 – 6. The sum of the weights of the various elements contained in a substance.

634 – 7. "Molar" and "normal" solutions.

634 – 8. 1 gram-molecular weight (1 gm mole) of a solute dissolved in 1 liter of solution.

634 – 9. Normality.

634 – 10.(1) The equivalent of an acid is the weight of the acid which contains 1 gram of hydrogen ion (replaceable hydrogen) or the molecular weight divided by the number of replaceable hydrogen atoms (ions) per molecule.

(2) The equivalent of a base is the weight which contains 17.008 grams of hydroxyl ions (replaceable OH), or the molecular weight divided by the number of hydroxyl radicals (ions) per molecule.

(3) The equivalent of a salt is that weight which contains one equivalent of its acidic or basic portion, or the molecular weight of the salt divided by the valence characteristics of the metallic or acidic group.

634 – 11. The atomic weight of iodine equals its equivalent weight. Thus iodine = 126.9 gm eq wt. Find 0.5 of the gm of eq wt 126.9 × 0.5 = 63.45 gm. Dissolve 63.45 gm of iodine in water to make 1 liter.

635 – 1. The concentration of the chemical in the sample is found by adding a measured amount of a specific reagent (titration) until the equivalent point (end point) of the reaction is reached. This equivalence point is found by the use of an indicator which changes color abruptly at the end point, or by using a specially designed potentiometer which measures electrical potential (voltage) across two electrodes in the solution.

635 – 2. Ferroin, indigo carmine, methyl orange, phenolpthalein, potassium chromate, and starch.

636 – 1. Because there may not be a suitable color change indicator for some solutions or because some solutions may be so highly colored that a color change cannot be seen.

636 – 2. Indicating; reference.
636 – 3. Inflection; break.
636 – 4. Concentric arc template.
636 – 5. "Delta."

637 – 1. Reagents because they react with other chemicals in a known manner.

637 – 2. Because an error introduced into the reagent standardization will produce an error in subsequent analyses.

637 – 3. A typical reagent is usable at some plus or minus normality deviation from a nominal value. In general, the accuracy of the standardized reagent is satisfactory if it is equal to the nominal value within an allowable tolerance.

637 – 4. At some plus or minus normality deviation from a nominal value.

637 – 5. When no expiration date is given, it is implied that the reagent is stable or its proposed use is such that a critical concentration is not required.

638 – 1. A chemical analysis of a sample is valid and useful only when the samples analyzed are representative of the solution. A correct analysis of a nonrepresentative sample may do more harm than good in controlling the process.

638 – 2. So that they are representative of the solution at the prescribed sampling point.

638 – 3. To allow large particles to settle to the bottom and turbidity due to aeration to clear.

638 – 4. When the concentration of a precipitate in a solution is to be determined. Shaking the representative sample enables you to calculate the concentration of the precipitate in grams per liter.

638 – 5. Some paints or inks contain ingredients which may permeate polyethlene bottles and contaminate the sample.

638 – 6. The filling is done to exclude air and the capping is done to prevent any loss of volatile constituents.

638 – 7. To avoid aeration.

639 – 1. Mono-methyl-para-aminophenol sulfate, commonly called Metol, and hydroquinone, chemically known as para-dihydroxy-benzene.

639 – 2. Cerimetric. Because it depends on a change of color to determine the end point at which the reaction of reduction-oxidation is complete.

639 – 3. By mixing the sample with water-saturated ethyl acetate.
639 – 4. At a pH of 7.8.
639 – 5. Phosphate.

639 – 6. Ethyl acetate, containing both developing agents is acidified with H_2SO_4 and sodium sulfate making possible the separation of developing agents.

639 – 7. By titrating the sulfate-cerate to a color change end point.

639 – 8. By the change in color from orange to light green or clear in fresh mixes and orange to greenish-blue in seasoned mixes.

639 – 9. A number of reagent and indicator solutions.

639 – 10. The blank is the ml of cerate titrated into a solution containing no Metol or hydroquinone before a color change is noted.

639 – 11. After extraction, 1.6 percent of the Elon is retained in the ethyl acetate layer and 1.8 percent of the HQ is retained in the aqueous layer.

639 – 12. The buffer should be at pH 7.9 and at 80°F.

640 – 1.
- a. Extraction of hydroquinone and Elon.
- b. Separation of the two developing agents.
- c. Preparation of a sample for the titration of Elon.
- d. Preparation of the top layer for the titration of HQ.
- e. Titration of the Elon.
- f. Titration of the HQ layer.
- g. Calculations.

641 – 1. Sulfate substantially cuts down the rate of aerial oxidation of hydroquinone and Metol. This action enhances the storage properties of developer solutions and increases the stability of solutions used in spray development.

641 – 2. Sulfonates are formed.

641 – 3. The mild solvent action of sulfite on silver halide appears to increase the rate of development of grains in the low exposure region so that it approaches the rate of development in more highly exposed regions in many emulsions.

641 – 4. The method uses a color change to indicate the end point. Follow these steps:
(1) Place 25 ml of the 0.1–N iodine solution into a 250-ml Erlenmeyer flask.
(2) Add 5 ml of concentrated hydrochloric acid and 50 ml of distilled water.
(3) Fill a 10-ml buret with the developer sample and titrate into the flask until the brown color of the iodine is bleached to the color of light straw.
(4) Add 2 ml of the starch indicator. The solution will turn blue. Continue titration until the blue color disappears.
(5) Calculate the sulfite concentration with this equation:

$$\frac{(\text{ml iodine})\ (\text{N of iodine})\ (63)}{\text{ml of developer}} = \text{grams/l of sulfite}$$

642 – 1. It acts as an accelerator and activator of the developing agent.
642 – 2. Induces a softening and swelling effect in the gelatin.
642 – 3. Because the pH must be kept at a specific value throughout the development.
642 – 4. Standardized 1–N hydrochloric acid to a gray end point.

643 – 1. On the reaction of sulfuric acid with normal carbonate, bicarbonate, normal sulfite, and bisulfite.
643 – 2. Phenolpthalein and modified methyl orange.
643 – 3. The "T" is the total volume of acid used in the titration.

644 – 1. Since the bromide in developing solutions increases as the solutions are used and since bromide acts as a restrainer, the amount of this chemical that is permitted to remain in the developer is quite critical.
644 – 2. Decreases the solvent action of sulfite.
644 – 3. The titrimetric method which depends on a color change to signal the end point.
644 – 4. The color changes from blue-black to red and the silver bromide precipitate coagulates.

645 – 1. The requirement on sodium carbonate is that it produce a pH known to give good results. Sodium carbonate may vary in alkalinity between batches and unless this degree of variation is known and compensated for, its use will not produce the expected results. Therefore, new or suspected batches are compared to an acceptable "standard" batch.

646 – 1. Phenidone is more energetic than Metol and less is required in the developer formula. Phenidone resists exhaustion and can be used longer than MQ developers. Its toxicity is less than Metol.

It is a low contrast developing agent that can be used in place of Metol at about 1/10 of the Metol concentration in most of the MQ systems.

647 – 1. A color change to determine the end point.
647 – 2. You titrate with 0.500–N sulfato-cerate until the Ferroin indicator changes to a greenish yellow.

648 – 1. Borax; carbonate.
648 – 2. The borates maintain a buffering action and disassociate more slowly in solution. The neutralization of hydrogen ions liberated during the development process by action of the borates provides a buffering action. The hydrogen ions lower the pH (increase the acidity) of the solution; and if they are neutralized as they are released, the pH remains constant.

CHAPTER 4

649 – 1. Float a hydrometer in the solution.
649 – 2. For reference to pure or distilled water at 60°F.
649 – 3. The temperature of the solution being checked is rather critical. An increase of 3°F. causes a decrease of about 0.001 in specific gravity reading.
649 – 4. The applications of specific gravity are used in water carryover. The actual dilution of developer is compared with a fresh developer. Another application is the comparison of fresh fixing bath to a used fixing bath. The silver content of the bath increases through use.
649 – 5. Most of the specific gravity readings are not necessarily definitive as to what is wrong. They simply indicate a change which can be the signal for further testing.
649 – 6. By a reduction in specific gravity.

650 – 1. A fresh mix of developer is evaluated and its pH is established. This value is maintained throughout the processing. Samples of the developer are taken at intervals and quickly checked for pH. The pH of a solution in use can be monitored during processing, and timely adjustments can be made to the solution.
650 – 2. Increase; decrease.
650 – 3. Fog generally increases relative to image development as the pH increases.
650 – 4. The developing agent, its concentration, as well as the amount of sodium sulfite used.
650 – 5. Since the reaction of the developer with the silver halides liberates acid, the buffering action of the alkali (its ability to maintain a particular pH) is most important.
650 – 6. Previous readings with the same system have established upper and lower control limits. As your pH starts to drift toward either control limit, you carefully monitor the shift. At some point you may have to take corrective action if the shift continues.
650 – 7. Temperature, replenishment supply malfunction, large expanses of heavily exposed film, etc.
650 – 8. The key word is "standardization." In other words, standardize everything except the one variable you are striving to analyze.

651 – 1. Temperature.
651 – 2. Temperature coefficient is the ratio of the development rate at a particular temperature to the rate at a temperature 10° lower on the Centigrade scale, or 18° lower on the Fahrenheit scale.
651 – 3. Increase; increase.
651 – 4. Restrainer.
651 – 5. Exposure.
651 – 6. a. t.
b. T.
c. C.
d. k.

652 – 1. Calcium, magnesium, flouride, mineral acidity, silica, sodium and potassium salts, hydrogen sulfite, iron, manganese, carbon dioxide, methane, oxygen, nitrogen, chlorine, copper, lead, zinc, turbidity and sediment, pigment, microbiological growth, algae, and slime.
652 – 2. The measure of the calcium (Ca) and magnesium (Mg) ions in the water.
652 – 3. May precipitate out as carbonates, sulfites, phosphates, or borates.
652 – 4. Add sequestering agents such as "Calgon" or "Quadrafos."

653 – 1. Gravimetric analysis (for Ca and Mg), colorimetric titrations, soap test, palmitate titration, and soda reagent procedure.
653 – 2. The soap test and the colorimetric titrations.
653 – 3. In ppm as calcium carbonate.
653 – 4. Magnesium salt.
653 – 5. The EDTA determination of total hardness.
653 – 6. A buffer, an indicator, a standard calcium carbonate solution, and EDTA solution.
653 – 7. 100-ml sample size.
653 – 8. The water sample solution should be clear, and the color change is from wine-red to pure blue.

654 – 1. A standard silver nitrate solution is used.
654 – 2. By adding 4 to 5 drops of phenolpthalein indicator plus sulfuric acid to make the pink solution turn colorless.
654 – 3. Turns the colorless solution to a bright yellow.
654 – 4. A permanent reddish color.
654 – 5. That the solution is in the alkaline state.
654 – 6. This equals P (phenolpthalein) alkalinity in ppm.
654 – 7. A yellow color.
654 – 8. The figure equals the M (methyl-orange) alkalinity in ppm.
654 – 9. The several ions contributing to the alkalinity, including carbonate, bicarbonate, hydrate, phosphate, and silicate.

655 – 1. Ion-exchange water softeners, filters on your in-plant water lines, ion-exchange units, corrosion inhibitors, and ion-exchange dealkalizing or dimineralizing units.
655 – 2. Soft water as long as the ion-exchange resin is properly maintained and regularly regenerated.
655 – 3. Filters on your in-plant water lines.
655 – 4. Objectional color may be coagulated with alum and activated carbon and removed in settling tanks.

656 – 1. To determine the analyzed quantity of components present in the mix.
656 – 2. You run a sensitometric test on the fresh mix and decide what limits you must maintain.
656 – 3. On the sensitometric limits that your program can tolerate.
656 – 4. On the basis of chemicals lost and gained.

657 – 1. (1) Certain components become exhausted.
(2) Bromide ions are released into the solution.
657 – 2. Replenishment must occur.
657 – 3. First, the quantity is less due to evaporation and carryout. Second, its pH is lowered; and its alkali, developing agents, and preservative are reduced in strength and quantity. Also, the exhausted solution contains an increased amount of bromide ions plus waste products, such as redox products, gelatin, sensitizing dyes, antihalation dyes, and free silver. Third, it contains foreign matter, i.e., dust and dirt.
657 – 4. The action causes a restraining activity and results in the loss of shadow density and increased contrast.
657 – 5. To control the bromide buildup.
657 – 6. As a result of: (1) depletion of the developing agent or agents, and (2) the restraining effects of the byproducts.

658 – 1. Your replenisher program is based on statistical evaluations of your process.
658 – 2. You consider these factors: The standards set for your certified solutions must be met. If solutions have been modified, the replenisher must be calculated for the modified formula. If additions have been made to an existing developer, you decide whether or not the additions constitute a modification to be continued.
658 – 3. Take a measured amount of the developer in question, analyze it, exhaust it, measure it for volume, and analyze it again for content.
658 – 4. Water is added to dilute the bromide and to provide a vehicle for the alkali, developing agents and preservatives which replace those constituents exhausted from the developer.

659 – 1. The first step to consider in calculating a replenisher formula is to determine the criterion for exhaustion. You might use gamma, D_{max} and/or ΔD (density difference between two selected points as your criterion).

660 – 1. As soon as the first film is placed in the solution and carried on simultaneously with development.

660 – 2. Sodium hydroxide is used to overcome excessive Br^- ion buildup; its buffering capacity is low and the pH of the solution fluctuates; therefore, the process must be monitored frequently.

660 – 3. Your control charts.

661 – 1. A limiting factor in achieving greater extended tank life is silver buildup. A satisfactory replenishment system must include the removal of silver from the solution. With high production rates, the recovery of the silver is practical and economical.

661 – 2. The most useful method precipitates the silver by electrolysis.

661 – 3. You can determine the amount of silver (grams per liter) in a fixing bath by using an argentometer.

662 – 1. Every 15 to 20 feet of 35-mm film per liter of total bleach solution.

662 – 2. Work under an exhaust hood and wear rubber gloves and goggles.

662 – 3. Uncombined bromine is circulated into the machine tank.

662 – 4. "Conditioned" by adding 5 grams per liter of potassium ferrocyanide.

662 – 5. After an equal volume of used bleach has been drained and discarded from the machine tank.

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STOP-

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 04A 01

CHEMICAL ANALYSIS AND PROCESS CONTROL

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (600) Specific gravity is a characteristic of a particular solution at a specific
   - a. relative humidity.
   - b. relative density.
   - c. temperature.
   - d. statistic.

2. (601) What decrease in specific gravity of a solution will be caused by an increase of only 5° F. in the temperature of the solution?
   - a. 0.001.
   - b. 0.010.
   - c. 0.100.
   - d. 1.000.

3. (601) Use the formula

$$\text{Specific gravity} = \frac{W_c}{W_w}$$

to work the following problem. If distilled water weighs approximately 1.0 gm/ml at 20° C., what is the specific gravity of 1 ml of a chemical that weighs 1.39 gm/ml at the same temperature?
   - a. 1.93.
   - b. 1.84.
   - c. 1.39.
   - d. 1.11.

4. (602) Standards for specific gravity for photographic solutions are generally determined by preparing standard mixes at
   - a. 72° F.
   - b. 70° F.
   - c. 68° F.
   - d. 65° F.

5. (602) When specific gravity measurements of a photographic solution deviate beyond control limits, you should
   - a. pull a complete chemical analysis of the solution.
   - b. correlate them with appropriate dip tests.
   - c. pull another sample and do another reading.
   - d. compare the analysis with the makeup formula.

6. (603) Why shouldn't you weigh sodium hydroxide in an aluminum dish?
   - a. Because sodium hydroxide is an acidic chemical.
   - b. Because sodium hydroxide is a putrid chemical.
   - c. Because sodium hydroxide is a pungent chemical.
   - d. Because sodium hydroxide is a caustic chemical.

7. (604) How should you compute the rest point of a balance beam?
   - a. Average of the right minus the average of the left.
   - b. Average of the left plus the average of the right.
   - c. Average the average of the right plus the average of the left.
   - d. Average the average of the left minus the average of the right.

8. (605) The smallest weight that can be measured by a balance is called its

a. sensitivity.
b. sensibility.
c. zero point.
d. rest point.

9. (605) When you slowly add or subtract chemicals in the left pan of a beam-type analytical balance, you are determining what balance point?

a. Accurate.
b. Approximate.
c. Sensitivity.
d. Sensibility.

10. (606) Identify the correct formula used to determine the amount of chemicals to be added or subtracted from the weighing dish of a beam-type analytical balance.

a.

$$\frac{\text{Rest Point} - \text{Zero Point}}{\text{Sensibility}}$$

b.

$$\frac{\text{Rest Point} + \text{Zero Point}}{\text{Sensibility}}$$

c.

$$\frac{\text{Zero Point} + \text{Rest Point}}{\text{Sensibility}}$$

d.

$$\frac{\text{Zero Point} - \text{Rest Point}}{\text{Sensibility}}$$

11. (607) The *true* weight of a solid can be determined by weighing the material in

a. air.
b. fluid.
c. a vacuum.
d. gas.

12. (607) Porcelain or glass objects that have been wiped will dissipate their electrical charge more rapidily in an atmosphere having which of the following characteristics?

a. Low relative humidity.
b. High relative humidity.
c. Low temperature.
d. High temperature.

13. (608) A representative balance of the substitution type is accurate to how many milligrams?

a. ±5.0.
b. ±0.50.
c. ±0.05.
d. ±0.005.

14. (609) The typical laboratory pH meter operates within the pH range of

a. 0 to 6.
b. 0 to 7.
c. 0 to 13.
d. 0 to 14.

15. (609) The temperature of a laboratory pH meter can be compensated manually between

a. 10° C. and 40° C.
b. 10° C. and 50° C.
c. 20° C. and 50° C.
d. 20° C. and 50° C.

16. (610) To avoid erratic readings caused by the presence of the pH meter operator, the face of the meter is covered with

a. acrylic plastic.
b. an acid coating.
c. an alkali coating.
d. an antistatic solution.

17. (610) What kind of solution should you use to clean dirt and stains from the instrument case and meter face of a pH meter?

a. Mild acetic acid.
b. Mild detergent.
c. Diluted acetone.
d. Diluted alcohol.

18. (610) Which input into a pH meter must be maintained to assure the accuracy of pH measurements?

a. Impedance.
b. Voltage.
c. Amperage.
d. Current.

19. (610) Stubborn capillary plugs in the liquid junction reservoir of a pH meter can be dissolved by immersing the liquid junction reservoir in warm

a. alkali solution.
b. distilled water.
c. acidic solution.
d. detergent solution.

20. (611) What condition of water determines how rapidly scale will accumulate in a boiler or evaporator of a water still?

a. Softness.
b. Hardness.
c. Sodium ions.
d. Potassium ions.

21. (612) What type of chemical solution is used in the chemical precipitation silver recovery method?

a. Sodium bromide.
b. Sulfuric acid.
c. Sodium sulfite.
d. Sodium hydroxide.

22. (612) Which of the following is *not* a function of silver recovery from film processing?

a. To save a precious metal.
b. To increase the efficiency of the fixing bath chemicals.
c. To raise or lower the fixing bath pH.
d. To make a profit.

23. (613) Imagery production specialists should use a grade of photographic chemicals that meets

a. ACS standards.
b. Technical standards.
c. Primary standards.
d. ANSI standards.

24. (613) Which quality designation is used to identify a chemical of exceptional purity that is used for preparing reference standards?

a. Primary Standard.
b. Reagent Grade.
c. Chemically Pure.
d. Purified Grade.

25. (614) In solution preparation, what kind of controls must you maintain over the chem-mix function?

a. Loose.
b. Rigid.
c. Reasonable.
d. Routine.

26. (615) The structural material used extensively in chemical mixing and storage equipment because of its strength and durability is

a. stainless steel.
b. glass.
c. plastics.
d. hard rubber.

27. (615) To minimize the vortex produced in a chemical mixing tank by the on-center propeller type agitator, which of the following can be placed in the tank?

a. Stirrers.
b. Dividers.
c. Baffles.
d. Filters.

28. (615) Contact of the metal of a photographic solution tank with dissimilar metals tends to induce

a. corrosion.
b. subversion.
c. submersion.
d. corruption.

29. (616) How many inches below the surface of a photographic solution should a representative aliquot be drawn for a volumetric analysis?

a. 4″.
b. 3″.
c. 2″.
d. 1″.

30. (616) In general, how many minutes should you allow a sample bottle to stand after being taken from the photographic processing solution before analysis?

a. 5.
b. 10.
c. 15.
d. 20.

31. (617) When curves are plotted for a sensitometric certification of a photographic solution, which of the following can you use as a reference standard?

a. Gamma.
b. Delta density.
c. Average gradient.
d. Any of the above.

32. (617) How often should you agitate the stainless steel dip test tube filled with newly mixed developer and loaded dipstick?

a. Once each minute.
b. Twice each minute.
c. Once every 2 minutes.
d. Twice every 3 minutes.

33. (618) Which of the following tests is *not ordinarily* required in the chemical certification of a processing solution?

a. Determining the pH.
b. Cerimetric determination.
c. Total alkalinity.
d. Specific gravity.

34. (618) In order to measure the electrical potential between the glass electrode of a pH meter and the solution surrounding it, what reference is used to complete the circuit?

a. Sodium ions.
b. Liquid junction.
c. Buffer.
d. Calomel electrode.

35. (619) Any glass electrode gives erroneously low pH values of alkaline solutions containing

a. sodium ions.
b. potassium ions.
c. hydrogen ions.
d. hydroxyl ions.

36. (619) To reach a proper state of equilibrium with an aqueous solution, new electrodes should be soaked in distilled water for

a. 1 hour.
b. 2 hours.
c. 3 hours.
d. 4 hours.

37. (620) What type of buffer is used to calibrate the pH meter and the electrode assembly?

a. Secondary standard.
b. Primary standard.
c. Borax.
d. Calcium chloride.

38. (620) If you are cross-checking the electrodes of a pH meter and the upper and lower control limits for the borax buffer are 9.26 and 9.16 at 70° F. and your cross-check reading shows 9.01, you should

a. continue with the procedure.
b. report your sample results.
c. accept all the results.
d. replace the faulty electrode.

39. (621) To determine the pH value of a single sample, you should lower the electrode assembly into a beaker of the sample and set the timer for

a. 1 minute.
b. 2 minutes.
c. 3 minutes.
d. 4 minutes.

40. (622) If a situation requires a multiple sample pH determination, the cross-check is repeated after which sample measurement?

a. Second.
b. Fourth.
c. Sixth.
d. Eighth.

41. (623) When determining the pH values of a successive group of samples, you should take which of the following values?

a. Standard.
b. Sigma.
c. Average.
d. Range.

42. (624) The E-O-X indicator is used in the total alkalinity test because it shows an abrupt change at or near what pH?

a. 9.6.
b. 7.5.
c. 5.4.
d. 4.3.

43. (624) A potentiometric titration value for total alkalinity is the same as the

a. milliliter amount of 0.1-N sulfuric acid to obtain a pH of 4.3.
b. maximum reading on the pH meter scale.
c. amount of E-O-X needed to produce a gray color.
d. pH meter scale reading when the pushbutton is released.

44. (624) In preparing alkalinity analyses, what must you always specify about the sample?

a. ml of titrant.
b. Indicator.
c. Buffer.
d. Size.

45. (625) At what pH range is the thiosulfate fixing bath with potassium alum normally used as a hardening agent?

a. Above 4 and below 6.
b. Above 3 and below 5.
c. Above 4 and below 7.
d. Above 3 and below 6.

46. (625) When potassium alum is used as a hardening agent in a fixing bath, its hardening action reaches its peak at what pH value?

a. 3.
b. 4.
c. 5.
d. 6.

47. (625) Normally, the fixing bath solution is buffered against an increase in pH by

a. sodium hydroxide.
b. potassium alum.
c. phenolpthalien.
d. acetic acid.

48. (626) When reporting the total acidity of a solution, you must always indicate the

a. normality of titrant.
b. type of indicator.
c. method of determination.
d. sample size titrated.

49. (627) The silver content of a fixing bath solution is proportional to the optical density of the

a. discoloration.
b. transmission.
c. dissemination.
d. turbidity.

50. (627) The meter dial of the argentometer is calibrated in terms of grams/liter of

a. bromide.
b. chloride.
c. silver.
d. aluminum.

51. (628) when the result of an analysis agrees with a known value, we say that the result is

a. biased.
b. prejudiced.
c. accurate.
d. reliable.

52. (629) The measure of a spread in the range of repeated results in a chemical analysis is called

a. reliability.
b. validity.
c. accuracy.
d. precision.

53. (630) Where a preparation formula calls for an accuracy in grams of three decimal places, it means what fraction of a gram?

a. 1/10.
b. 1/100.
c. 1/1000.
d. 1/10,000.

54. (630) The pans of an analytical balance may be protected by all the following *except*

a. aluminum dishes.
b. filter paper.
c. watch glasses.
d. weighing bottles.

55. (631) The standard unit of volume in the metric system is the

a. quart.
b. gram.
c. meter.
d. liter.

56. (631) Which solution is *not* recommended for cleaning glassware?

a. Hydrofluoric acid.
b. Sulfuric-dichromate.
c. Nacconol.
d. Acid-alcohol.

57. (632) The temperature at which volumetric vessels are calibrated is

a. 15° C.
b. 20° C.
c. 25° C.
d. 30° C.

58. (633) When liquid is contained in a narrow cylinder, the upper surface of the column of the liquid takes on a curved shape due to

a. osmosis.
b. gravity.
c. capillary action.
d. inversion.

59. (633) When using a graduated cylinder of liquid, what part of the meniscus should you take as a reading?

a. Vertical plane.
b. Horizontal plane.
c. Highest point.
d. Lowest point.

60. (634) How many parts of water should you use to prepare a 28 percent acetic acid solution from a 99-percent acetic acid solution?

a. 14.
b. 28.
c. 71.
d. 99.

61. (634) The sum of the weights of the various elements contained in a substance is called the

a. atomic weight.
b. ionic weight.
c. formula weight.
d. molecular weight.

62. (634) The method of expressing the concentration of a solution based on the equivalent weight of the solute is called

a. formality.
b. molarity.
c. molality.
d. normality.

63. (634) The weight of a solute that is needed to make 1 liter of a 1-normal (1N) solution is

a. 1 gram atom.
b. 1 gram molecule.
c. 1 gram equivalent.
d. 1 gram ion.

64. (635) The concentration of a chemical in a sample is found by adding a measured amount of a specific reagent until what point is reached?

a. Aim.
b. End.
c. Amber.
d. Even.

65. (635) What color does litmus paper turn at a pH of 8.3?

a. Blue.
b. Green.
c. Yellow.
d. Purple.

66. (636) What type of indicating electrode is used in the pH meter for acid-base titrations?

a. Glass.
b. Calomel.
c. Hydrogen.
d. Silver.

67. (636) When used for the titration of halides with silver nitrate, the reference electrode is filled with

a. potassium bromide.
b. potassium chloride.
c. potassium nitrate.
d. potassium iodide.

68. (636) In potentiometric titration, the point at which the curve changes its direction of curvature is known as the

a. aim point.
b. titration point.
c. end point.
d. inflection point.

69. (637) Instructions for mixing most reagents are written for the preparation of what quantity?

a. 1 liter.
b. 1 quart.
c. 1 gallon.
d. 1 kilo.

70. (638) How many minutes after you have taken a sample of the processing solution should you let the sample bottle stand?

a. 5.
b. 10.
c. 15.
d. 20.

71. (638) Before taking a sample, what kind of a solution should you use to clean the bottle and bottle caps?

a. Detergent.
b. Sulfuric-dichromate.
c. Acid-alcohol.
d. Distilled water.

72. (638) How many inches below the surface of the mix tank do you submerge the sample bottle when sampling the mix tank solution?

a. 1".
b. 2".
c. 3".
d. 4".

73. (638) When you sample non-recirculated solutions, you draw a representative solution into

a. a test tube.
b. a syringe.
c. a buret.
d. a hydrometer.

74. (639) A developing method that depends on a change of color to determine the end point at which a reduction-oxidation reaction is complete is called

a. titrimetric determination.
b. volumetric determination.
c. cerimetric determinations.
d. stoichiometric determination.

75. (639) Which of the following indicators is used to introduce color to the Elon and hydroquinone samples?

a. Methyl red.
b. Phenolpthalien.
c. Ferroin.
d. Starch.

76. (640) Which step in the determination of Elon and hydroquinone is accomplished after the hydroquinone layer is titrated?

a. Extraction of hydroquinone and Elon.
b. Titration of the Elon.
c. Calculations.
d. Separation of two developing agents.

77. (641) The reaction of Metol and hydroquinone with silver bromide in the presence of sulfite tends to liberate

a. oxygen.
b. a salt.
c. a base.
d. an acid.

78. (641) If 15 ml of 0.1-N iodine was used in determining sulfite concentration and 3.03 ml of developer was required to reach an end point, calculate the grams/l of sulfite in the mix. Use the following formula:

$$\frac{(\text{ml of iodine})\ (\text{N of iodine})\ (63)}{\text{ml of developer}} = \text{grams/l of sulfite}$$

a. 15.6 grams/l.
b. 31.2 grams/l.
c. 63.3 grams/l.
d. 94.5 grams/l.

79. (642) Which developing agent can function in an acid environment?

a. Kodalk.
b. Borax.
c. Boric acid.
d. Amidol.

80. (642) A function of sodium carbonate in a developer is to

a. reduce solution pH.
b. increase specific gravity.
c. soften the emulsion.
d. decrease developer diffusion.

81. (643) If you add phenolphthalien to a solution of sodium carbonate, the solution will turn pink. You can expect that with a gradual addition of an acid, the solution will become

a. purple.
b. green.
c. blue.
d. colorless.

82. (644) Potassium bromide is often added to fresh developer to produce

a. a D log H shift to lesser values.
b. increased shadow density.
c. physical development.
d. less fog.

83. (644) Select the method that is a typical procedure for bromide determination.

a. Titrimetric.
b. Volumetric.
c. Potentiometric.
d. Gravimetric.

84. (645) In what kind of containers should the reference standard sodium carbonate be stored?

a. Friction.
b. Static.
c. Tensile.
d. Airtight.

85. (646) Phenidone has a tendency to produce fog with high speed emulsions. What material may be added to lower this tendency to an acceptable minimum?

a. Antihalation.
b. Antifoggant.
c. Antisensitizer.
d. Antireduction.

86. (647) In the Phenidone determination, for how many seconds is the developer sample shaken for separation?

a. 20.
b. 25.
c. 30.
d. 35.

87. (648) Sodium thiocyanate in a developer solution acts as a

a. silver solvent.
b. fogging agent.
c. restrainer.
d. preservative.

88. (648) Distilled water used in preparing a borax buffer should have a pH value of

a. 5.5.
b. 7.0.
c. 8.5.
d. 9.0.

89. (649) Which of the following is defined as the relative density of a substance (solution) compared with the density of distilled water?

a. Total alkalinity.
b. Relative humidity.
c. Specific gravity.
d. Barometric pressure.

90. (649) The scale in a hydrometer is calibrated for reference to distilled water at

a. 40° F.
b. 50° F.
c. 60° F.
d. 70° F.

91. (650) What generally increases relative to image development as the pH increases?

a. Dust.
b. Fog.
c. Smog.
d. Stain.

92. (650) What compound has been used as the sole alkali in certain fine-grain developers in the pH range 7.8 to 9.0?

a. Sodium carbonate.
b. Sodium sulfite.
c. Sodium hydroxide.
d. Sodium bromide.

93. (651) Against what data should a mix of developer chemicals be certified?

a. Test.
b. Modified.
c. Altered.
d. Control.

94. (651) The temperature coefficient is the ratio of the development rate of a developer solution at a particular temperature to the rate at what lower temperature?

a. 5° C.
b. 10° C.
c. 15° C.
d. 20° C.

95. (652) What agent can be added to a processing solution to minimize the precipitation of calcium and magnesium?

a. Calgon.
b. Soap.
c. Trisodium phosphate.
d. Sodium hydroxide.

96. (653) In the soap test for hardness, the hardness of the water sample is expressed in ppm as

a. magnesium sulphate.
b. calcium carbonate.
c. sodium carbonate.
d. potassium hydroxide.

97. (654) When testing for impurities in the water supply, what standard solution is used to conduct a chloride test?

a. Silver nitrate.
b. Phenolphthalien.
c. Sulfuric acid.
d. Potassium dichromate.

98. (655) The water supplied by most municipal water systems is passed through a system of settling tanks and filters to remove sediment and

a. microbiologicals.
b. ion-exchange resins.
c. flocculence.
d. turbidity.

99. (656) When calculating a replenisher formula, what is the exhaustion point based on?

a. The sensitometric limits that can be tolerated.
b. A completely analyzed fresh mix.
c. A completely analyzed used mix.
d. The amount of bromide remaining in solution.

100. (657) The first consideration in designing a developer replenisher is to control what buildup?

a. Iodide.
b. Bromide.
c. Chloride.
d. Fluoride.

101. (658) The function of a replenisher in the developing process is to provide a means for controlling

a. the developing process.
b. the amount of development solution.
c. pH and specific gravity.
d. sensitometry.

102. (659) The calculation of a replenisher formula is based on the

a. amount of water added per remaining liter to dilute the bromide.
b. amount of water added per remaining liter to dilute the alkali.
c. concentration of HQ/metol in the original formula.
d. concentration of sulfite in the original formula.

103. (660) What can be used to overcome excessive alkalinity problems in developer solutions?

a. Dilution.
b. Acid.
c. Filters.
d. Strips.

104. (661) The most useful method of recovering silver from a fixing bath is by causing it to

a. precipitate.
b. oxidize.
c. reduce.
d. exhaust.

105. (661) What kind of instrument can be used to determine the amount of silver (grams per liter) in a fixing bath?

a. Ammeter.
b. Ohmmeter.
c. Argentometer.
d. Voltmeter.

106. (662) What is the recommended interval for rejuvenating the bleach by the addition of bromide per liter of total bleach?

a. 10 to 15 feet of 35-mm film processed.
b. 15 to 20 feet of 35-mm film processed.
c. 10 to 15 feet of 70-mm film processed.
d. 15 to 20 feet of 70-mm film processed.

END OF EXERCISE

MAIL TO: ECI, GUNTER AFS AL 36118-5643

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(54-75)

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9	Send course materials. *(Specify in "Remarks")* [ ] Not received [ ] Lost [ ] Damaged
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IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

Volume 4B

Chemical Analysis and Process Control

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Preface

IN THIS VOLUME of *Imagery Production Specialist*, we cover quality assurance through evaluation, certification and calibration of metrology equipment, and the test and evaluating of new material and equipment.

Chapter 1 discusses the evaluation tasks performed by the Imagery Production Specialist. From the results of these evaluations, intelligent decisions about the imagery production cycle can be made to improve the end product.

Chapter 2 discusses the certification and calibration of the metrology equipment used during the evaluation testing covered in Chapter 1. In addition, processors and processor support equipment are given special attention. As you have studied previously, this equipment must give consistent and repeatable results daily if the product quality is to meet established standards.

Chapter 3 covers procedures for testing and evaluating new materials and equipment and comparing the results with known characteristics of the materials and procedures presently in usage. As this chapter explains, a major role in these testing and evaluating procedures is the recording of the new data into reports that may be used by other personnel in solving future problems.

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Quality Assurance Through Evaluation

THERE ARE several ways in which you can evaluate the conventional metallic silver image. In this chapter we shall discuss one of the ways that evaluations can be done. Bear in mind that a reliable evaluation requires the use of such complex equipment as a microdensitometer. This instrument is very much like the conventional densitometer, except that very small areas of the total image are examined. Because such small areas are examined, another measurement is included in the density determination of an image; this is *distance*.

1-1. Image Evaluation

By this time, you've probably noted that there are many variables which exercise control over the bits and pieces of information comprising one photograph. As can be expected, some of these variables are outside your control. For example, the effects of sonic speeds of reconnaissance aircraft upon exposure, atmospheric attenuation of the image, degradation caused by the camera system, and extraneous radiations in space are not your problems. Your span of control begins with processing of the original film or with producing any of the required reproduction generations. With these limitations in mind, let us look over the evaluation tools that you have at your disposal.

663. State how independent parameters affect image quality, define and contrast graininess and granularity, and identify the factor that permits us to predict the informational capacity of the silver image.

Silver Image Evaluation. The particles forming the image cause an influence on many evaluative measurements. If the effects of variables are isolated, and if you have the means available for objectively evaluating image quality, then the effects can be related directly to the expected image quality. With this in mind, the variations that result in improved image quality can be perpetuated, while the variations that result in reduced image quality can be eliminated.

Along with grain, another term, *granularity*, is often confused with graininess. *Graininess* is a subjective thing *not* directly measurable. *Granularity*, on the other hand, *is* measurable; consequently, it can be used as a scientific tool. However, do not discount graininess—after all, although it is only a visual impression, the photointerpreter places considerable importance on such an impression.

Information content of the silver image is largely a function of granularity, with fine-grain images producing the greatest detail rendition. However, once we have established a certain granularity (achieved a desired maximum, average, and minimum size), we must consider other factors which also enable us to predict informational capacity. As a starting point, let us discuss the resolving power as it appears on the emulsion in the form of a silver image.

Exercises (663):

1. How are the effects of variables related to expected image quality?

2. Define graininess.

3. Define granularity.

4. One of the factors that enable us to predict the informational capacity of the silver image is __________ .

664. Cite the method of determining resolving power, compare the association of lens resolving power with emulsion resolving power, and state why, examined under a microscope, resolution test emulsions help us avoid high magnification and the optimum density level at which the maximum resolving power value is attainable.

Emulsion Resolving Power. Resolving power is one of the oldest measurements associated with the evaluation of a photographic image. Since its result is actually computed from the photographic reproduction, it is an excellent measure of an entire system. Based on previous concepts, we are now in an era of high resolution photography. In

World War II, resolution was about 15 lines/mm; but now we talk in terms of 150 lines/mm and higher.

The usual way of determining resolving power is to photograph a test object consisting of groups of lines and lines having a graded (square wave) frequency. This reproduction is then viewed with a magnifying device. The most closely spaced lines which can be distinguished as still being separated establish the resolving power. This distinction is a factor in the rendition of fine detail—a factor especially important in aerial photography. Notice the accent on fine detail. In a landscape, we view the entire photograph for the general effect of composition, shapes, and tonal balance. Conversely, the aerial photograph is viewed part by part in minute detail, using a magnifier or microscope, with just an occasional look at the whole. The big picture examination is for the purpose of identifying form, relationships, and structure as a prelude to detailed examination.

In the airborne vehicle, there are many factors influencing and degrading resolution. Your control over these factors is negligible. However, the processing is still to be considered. After processing comes the duplication, which is almost completely under your control. As a matter of fact, you may be able to increase the resolving power of the original during duplication. In any event, your job is to prevent any further degradation.

The resolving power of lenses is closely associated with emulsion resolving power (because a lens is part of the overall system), and each exerts it own effect. An entire system produces a given resolving power. If one lens system is substituted for another, there will be a corresponding change in resolution (either greater or lesser), and the results of the two lens systems are compared. If only emulsions are changed, then one emulsion is compared with another by examining final results. As long as only one factor is changed (such as lens, film development time, developer formula, etc.), its effect is identified in terms of resolution by comparing final results.

At this time, let us consider emulsion resolving power as a separate entity, one divorced from the optics of the system. However, from one test to another, the same optics must be used to standardize this one parameter. Any desired variation, depending upon the test, is then introduced.

Resolution tests of emulsions are read in the same manner as tests of lenses. After the test object is photographed at the desired reduction, processed, and dried, the negative is examined with a microscope at a comparatively low magnification, say, 50 to 100 power. Higher magnification is avoided, since it would show the individual grains of silver instead of the lines which the grains are forming. The target is viewed in an attempt to distinguish one line from another. It is not necessary that the lines be sharp as long as some separation between them is seen. The value of the smallest element of the test object that can be resolved is taken as the resolving power (the emulsion in this case). It should be noted that the resolving power value is the maximum attainable, regardless of the density at which it occurs. The optimum density can be at many levels with different emulsions. Thus, consideration must be given to the resolving power over the entire range of densities encompassed by the negative.

Exercises (664):

1. How do you determine resolving power?

2. What is the association between the resolving power of a lens and the resolving power of an emulsion?

3. Why is high magnification avoided when resolution test emulsions are examined under a microscope?

4. At what optimum density level is the maximum resolving power value attainable?

665. Using figures 1-1 and 1-2 and table 1-1, distinguish among the methods of resolution testing, using test objects suggested by the National Bureau of Standards, and state the two courses that are followed to obtain resolving power for other ranges and the point at which a lens' maximum resolving power occurs.

Resolution Testing Using Test Objects. Certain test objects are convenient for resolution testing inasmuch as they are used at any time of the day, are uniform in their structure, and provide the basis for easy computation. There are many types of test patterns and many methods of using them. However, they all have elements in common, and it is not necessary to discuss all types individually here.

The method suggested by the National Bureau of Standards is actually a test of the resolving power of the lens-camera-film system. However, it can be used to evaluate the resolving power of the lens when used with a film having a resolution capability at least three times greater than that of the lens.

The test object used is the National Bureau of Standards (NBS) Resolution Test Chart adopted in 1952. This chart consists of two series of three-bar patterns, differing from adjacent groups by approximately $\sqrt{2}$, and from opposite groups by $\sqrt[4]{2}$. There are two NBS test targets. One is the high-contrast chart with a contrast ratio of 1.4. A representative example is shown in figure 1-1. The other is a low-contrast chart having a ratio of 0.20 between the lines and the background.

To use the NBS targets, which are opaque, photograph them on a fine-grain high-resolution emulsion at a known reduction and examine the developed images through a

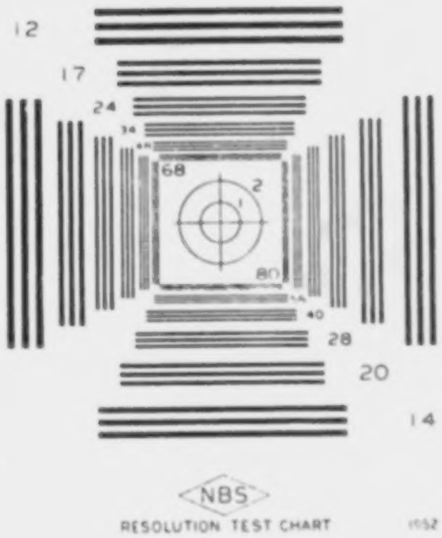


Figure 1-1. NBS resolution test chart.

low-power microscope to ascertain the number of distinguishable lines. The diagonally arranged numbers from 12 to 68 refer to the vertical lines on the left and to the horizontal lines at the top of the targets, and the numbers 14 to 80 pertain to the bottom and right-hand lines. These numbers indicate the lines per millimeter only when the targets are photographed at 25 × reduction. A 25 × reduction is obtained when the targets are placed 26 focal lengths in front of the lens.

If you desire to obtain the resolving power for other ranges, you may follow either of two courses. Your simplest course is to change the distance between the lens and the test chart, thereby altering the reduction ratio. The other is for you to change the target size by photographic means.

When the lens-to-target distance is changed, the values indicated on the test chart are corrected by the equation:

$$RP = (M/25)N$$

where RP = resolving power in lines per mm, M = the ratio of object to image size, and N = the number of a particular test pattern in the chart. Thus, for a 10 × reduction, the test pattern numbered 20 would indicate

$$(10/25)20 = 8 \text{ lines/mm}$$

and for a 50 × reduction, it would be

$$(50/25)20 = 40 \text{ lines/mm}$$

For any value of M, the distance the chart must be placed in front of the nodal point of the lens is given by the equation

$$D = (M + 1)f$$

where D = the distance expressed in units of the focal length of the lens, and f = the equivalent focal length of the lens. The value of D for a 12-inch lens used at 10 × reduction is

$$D = (10 + 1)12 = 132 \text{ inches, or 11 feet}$$

For a lens having a focal length of 50 mm, it would be

$$D = (10 + 1)50 = 550 \text{ mm}$$

For practical purposes, the distance D can be measured from the front surface of the lens being tested.

When the NBS test charts are used to determine resolving power at finite distances, the image plane of the lens does not coincide with the focal plane (the plane occupied by the image plane when the camera is focused at infinity distances). The separation between the image plane and the focal plane at reduction ratio M is given as

$$d = f/M$$

where d = the distance separating the image and focal planes. For a 10 × reduction with a 50-mm lens, the separation would be

$$d = 50/10 = 5 \text{ mm}$$

and for a 25 × reduction, it would be

$$d = 50/25 = 2 \text{ mm}$$

You can see from this that the value of *d* decreases as the amount of reduction increases.

By applying these equations, it is possible to figure a resolving power value at any finite distance, but most tests can be conducted at predetermined distances, therefore, table 1-1 is provided for your convenience.

The maximum resolving power of a lens occurs at its axis and, depending upon the symmetry of the lens, decreases as the angle from the axis increases. Therefore, a series of resolution targets arranged in lines in front of the camera indicates the resolving power of the lens over its entire surface. A typical arrangement of camera and target is shown in figure 1-2.

This basic arrangement is altered to give more extensive coverage. For instance, the row of targets may be placed in a diagonal relationship to the camera, or multiple rows of charts may be used.

TABLE 1-1

RESOLVING POWER CONVERSIONS FOR SEVERAL FIXED DISTANCES

M =	1	12.5	25	50	100
D =	2f	13.5f	26f	51f	101f
Pattern Number	Resolving Power in Lines/mm				
80	3.20	40	80	160	320
56	2.24	28	56	112	224
40	1.60	20	40	80	160
28	1.12	14	28	56	112
20	0.80	10	20	40	80
14	0.56	7	14	28	56
68	2.72	34	68	136	272
48	1.92	24	48	96	192
34	1.36	17	34	68	136
24	0.96	12	24	48	96
17	0.68	8.5	17	34	68
12	0.48	6	12	24	48

Exercises (665):

1. What is the method suggested by the National Bureau of Standards for resolution testing?

2. What kind of a test object has the National Bureau of Standards adopted for resolution testing?

3. How do you use the NBS targets?

4. What do the diagonally arranged numbers in the NBS target indicate?

5. If you decide to obtain resolving power for other ranges, what two courses may you follow?

6. Where does the maximum resolving power of a lens occur?

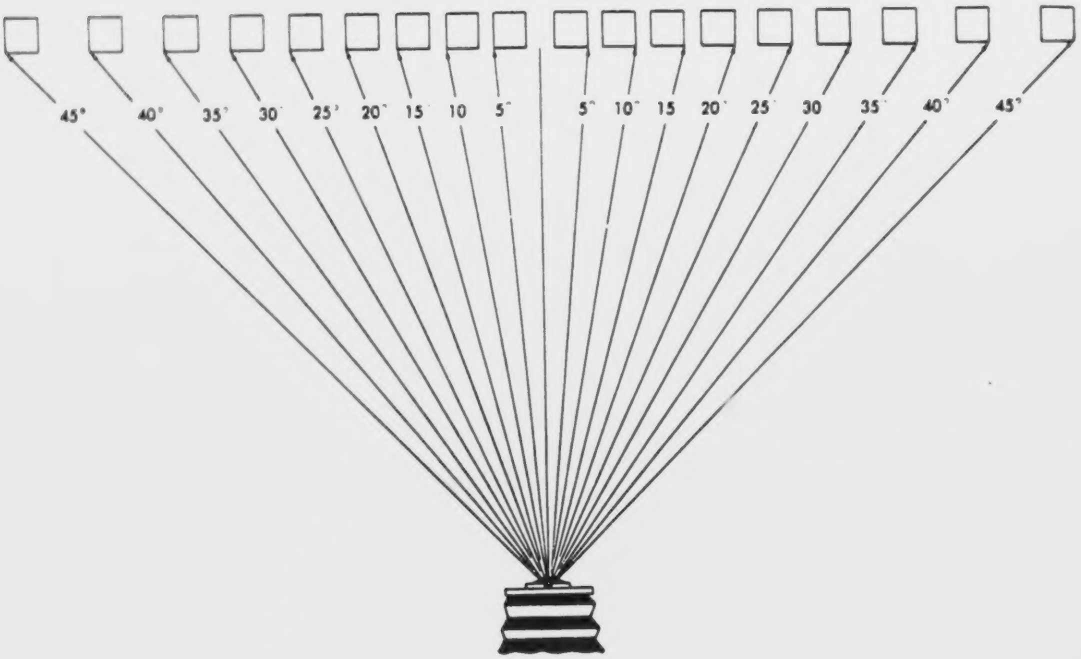


Figure 1-2. Arrangement of test objects for resolution testing.

666. State the main features of the USAF 1951 test object (or reticle) and the methods of producing the test image, and identify how the film's resolving power relates to the optical system (using fig. 1-3).

Test Targets. The resolving power test object can take many forms. A common target is the USAF 1951 test object (or reticle), shown in figure 1-3. Unlike the NBS target, this is a transparency and has an emulsion coated on a glass case. The glass, of course, has a high degree of dimensional stability.

The most popular test patterns used in this country are similar to the target shown in the preceeding illustration in that they follow a tricolumnar arrangement. Usually the widths of the columns and the spaces between them are equal. However, the width of the columns does not seem to have as much effect upon resolving power as does the length of the columns—longer lines being easier to distinguish than short ones. Therefore, long-line targets should be avoided, since they contribute to apparent high resolution which is not really present.

A classic example of this apparent high resolution was exhibited in a photograph taken from a Viking rocket in 1948. The photograph clearly shows the railroad from El Paso to Alamogordo on a photograph having a 300- to 500-foot ground resolution. By considering resolution, the railroad should not be apparent, but it was. This same phenomena in the imaging of a long-line resolution target could produce a similar spurious resolution. In an attempt to solve this and other problems, numerous patterns are devised. Among these are patterns looking like a sunburst, doughnut, doughnut with a broken segment, disks in a hexagonal array, divided square, block letters—such as the letter E—and many forms of 1-, 2-, 3-, and 4-line structures.

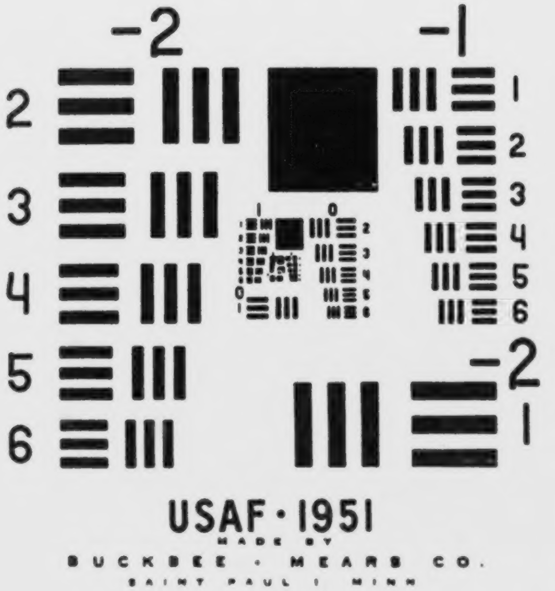


Figure 1–3. USAF 1951 test objects.

The test target used in resolving power measurements is a very precise instrument. You can see that errors which exist in the target are also transmitted to the measurement. Master test reticles are made by coating a glass plate with an opaque substance and etching out the transparent portions. This method is difficult, especially in the extremely small target areas. Also, targets are made one at a time and the costs are excessive. Furthermore, only high-contrast targets are produced in this manner.

Ordinarily, photographic reproductions are made from master reticles such as these, either on paper, plates, or film. Other methods require that a large original subject be constructed and photographed at predetermined reductions to produce the master reticle. Too much importance cannot be placed on these test targets, since practically every test of the various components of a photographic system includes their use. For quantitative studies, line patterns are found to do better than points. Over a century ago, Foucault described a test pattern consisting of many lines and spaces of equal width. By using a series of patterns of decreasing line separation, i.e., increasing spatial frequency, the finest pattern in which the image of the lines could be distinguished could be determined easily by observing the image place through a microscope. Thus, the standard definition of resolving power became: "The greatest number of line-pairs, or cycles-per-millimeter, a human observer can barely distinguish in the image of a crenelate (square wave) target."

When photographic emulsions come into use, it is logical that the concept of resolving power is extended to the evaluation of photographic image quality. The test-target image is produced either by contact printing or by exposing the film in a good camera. Difficulty in obtaining perfect contact limits the contact-printing method severely. However, exposing the film in a camera is more advantageous since, with reductions of 10:1 to 100:1, extremely fine test targets are not necessary.

Regardless of how the film is exposed, the resolving power of the film cannot be specified independently of the optical system that produced the latent image. The resolving power of a photographic material is, therefore, actually the resolving power of the lens-film system, and the values cannot be separated accurately. A useful approximation for isolating the resolving power of the film from that of the optical system is given, however, by the relationship:

$$\frac{1}{RP_{\text{film}}} = \frac{1}{RP_{\text{lens - film system}}} = \frac{1}{RP_{\text{lens}}}$$

Because the effects of the optical system cannot be isolated accurately in measuring film resolving power, the resolving power camera must be well designed. The objective lens must be corrected and be wide-aperture to minimize diffraction. The film plane must be perfectly flat so that the focus is uniform.

Exercises (666):

1. Describe the USAF 1951 test object (or reticle).

2. How are test-target images produced?

3. Define "resolving power."

4. Can the resolving power of the film be independent of the optical system? Explain.

667. Using figures 1-4 and 1-5, list the factors that affect resolution measurement and state the method used to evaluate the final image.

Factors Affecting Resolution Measurement. Some factors that affect resolving power are as follows:

- Exposure level.
- Target contrast ratio.
- Target shape, if the images are evaluated by a human observer.
- Photographic development, if film is used.
- Image viewing methods.

The resolving power of photographic materials is highly dependent on exposure level. The peak values of resolving power generally occur where magnitude of exposure causes the average exposure to fall on the lower straight-line portion of the density-log exposure curve (fig. 1-4). Generally, only the maximum value of an exposure series is reported.

The measurement of resolution is also greatly influenced by target contrast ratio; i.e., the ratio of intensities between the target lines and background. Maximum possibility of recognition occurs when the contrast ratio between the lines and background is very high (above 1000:1). As the target contrast ratio approaches unity, the resolving power falls off rapidly (fig. 1-5). Because low-contrast ratios occur more often in practical photography (especially through atmospheric scatter in aerial photography), the accurate specification of resolving power requires the use of low-contrast targets as well as high-contrast targets. A commonly specified contrast ratio is 2:1, but there is no universal agreement as yet. Therefore, the target contrast must be specified when one is reporting values of resolution. (If no value is reported, it must be assumed that the target contrast was 1000:1 or greater.)

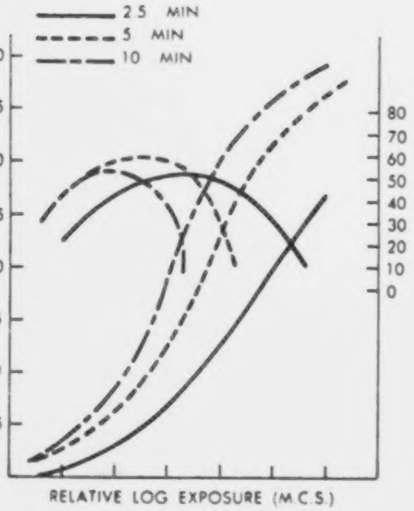


Figure 1-4. Resolving power as a function of exposure for three different developing times.

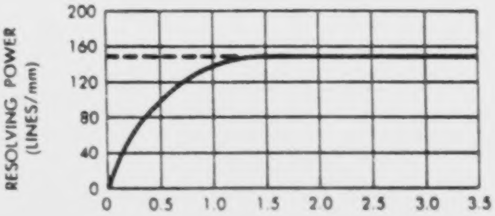


Figure 1-5. Resolving power variations.

The shape of test-target images exerts considerable influence on a human observer's measurement of resolution. It was agreed that the target should consist of equally spaced, equal-width line groups, but recently line length was questioned. Until this time, a long, fixed-line-length target was used, but now a three-line target with a fixed length-to-width ratio tends to reduce the maximum resolving power a human observer reports. Still, this reduction appears to be a more accurate quality appraisal of real images.

Resolving power depends upon the degree and nature of development in a very complex way (fig. 1-4). No all-inclusive generalizations can be made about the interrelationships; rather, the effects of development variations are determined by direct experiment with the particular materials. The only generalizations that appear to be justified are:

- Development variations that result in decreased graininess usually result in improved resolving power, and vice versa.
- For resolving power comparisons to be meaningful, the film should be processed as it is in practice.

The measured value of resolving power depends upon the method of evaluating the final image. Viewing conditions that are standardized by custom include the use of a binocular microscope and certain specified values of magnification. The human observer, however, cannot be specified, and there is considerable variability between human observers in judging resolving power. The variability occurs because resolving power is a threshold measurement, and the human-acuity threshold varies considerably.

Exercises (667):

1. What are the factors that affect resolution measurement?

2. What does the method of evaluating the final image depend upon?

1-2. Edge Response and Acutance

The "edge sharpness" (acutance) of a photographic image is of extreme importance. Acutance shows the ability of the photographic system to produce a sharp boundary between areas of the image that have received heavy and light exposure. While it may seem that resolving power and acutance are the same thing, experiments have shown that acutance and resolving power do not necessarily correlate. It has been proven that all emulsions (to varying extents) produce the edge between a heavy and a light density as a graded transition rather than a sharp demarcation.

Experimentation has shown that two different photographs of the same subject can result in having high resolving power and low acutance in one and low resolving power and high acutance in the other. Some developers tend to reduce acutance and, at the same time, have a lesser effect on resolving power. Generally speaking, however, procedures which tend to lower acutance also tend to lower resolving power.

668. Using figure 1-6, state the method for determining acutance, and the physical qualities of light as it passes over a sharp knife.

Acutance. The usual method used to measure acutance is to expose a piece of sensitized material, using a knife-edge opaque object to hold back exposure from one portion of the material. This produces two adjacent areas—one with, and the other without, exposure. After exposure and processing, the adjacent areas of the film are scanned with a microdensitometer.

Acutance is primarily a property of an emulsion. When light passes over a sharp knife edge, we *should* get a sharp demarcation line between the light and dark areas of the silver image. However, this is *not* the case, since the light is actually diffused into the area covered by the opaque object through processes of diffraction, reflection, refraction, and light scattering within the emulsion. Acutance is thus the objective measure of the ability of a photographic material to show a sharp line of demarcation between contiguous areas receiving low and high exposures. It correlates well with subjective judgments of picture sharpness. In addition to the gradient formed by a microdensitometer trace across the boundary, the abruptness of the toe and shoulder of the curve also has some bearing on acutance. If two materials with the same gradient are compared, the one with the most abrupt toe and shoulder produces the greater sensation of sharpness. The material with long sweeping toe and shoulder curves seems to produce an image which is not quite as sharp. In any event, values of acutance are usually based on an average of five microdensitometric traces of a knife-edge exposure.

The criterion of performance for a reconnaissance system is its capability to facilitate recognition of small detail. Acutance, or edge sharpness, plays a large part in detail recognition. As the altitude from which a reconnaissance photograph is taken increases, detail recognition becomes increasingly difficult to attain, since the detail is smaller and contrast is lower as a result of atmospheric attenuation. If the interpreter is to identify objects, it is necessary that the interpreter be able to establish object borders. Thus, it is your job to furnish a photograph having the necessary prerequisites.

Since detail rendition is of so much importance, it is necessary that the photographic system be planned around this factor. As we have already mentioned, there is a good correlation between acutance values and subjective judgment of picture sharpness (of so much importance to the interpreter). Thus, if the system produces high acutance values in the laboratory, we can predict that it will do the same under conditions of actual use. Note the objectivity of this sort is not applicable to resolution which depends upon many subjective factors, not the least of which is the visual acuity of the person making the test. Acutance, on the other hand, is a resultant of graphing a microdensitometric trace across a density variation border produced with a collimated exposing light. A comparison of traces across identically exposed borders on different emulsions produced under like conditions determines which emulsion has the better acutance, or any *other* single variable that is compared—such as developer formulary, time-temperature, drying, or any one parameter of the total system until the optimum acutance is obtained for this single parameter. Then some other factor may be varied until its optimum value is found. Finally, some total best system is evolved which produces the highest acutance.

After development of the knife-edge exposure, the exposure edge is scanned with a microdensitometer which measures the density change across the edge and the distance in which it is accomplished. These two measurements are used to produce a density-distance curve from which acutance is calculated. A typical curve of this type is illustrated in figure 1-6. Notice that instead of a sudden vertical transition from light to dark, we have traced a curve similar to a film characteristic curve. In order to compute an acutance value, the curve is divided into a number of small and equal increments by ticking off along the distance scale. The gradation value for each of these increments is then determined.

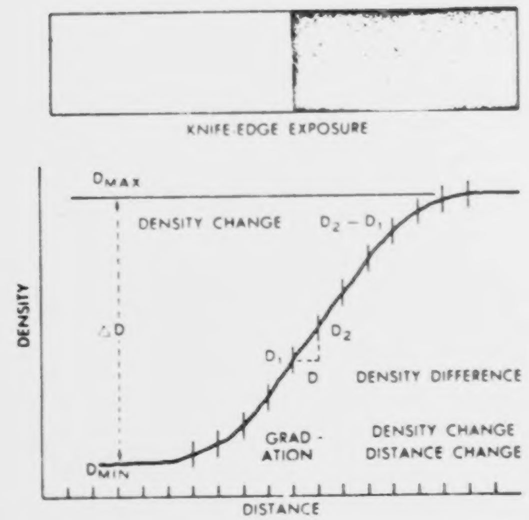


Figure 1-6. Acutance computation.

An acutal acutance calculation is made by dividing the horizontal distance of the microdensitometer trace into small equal segments, as shown in figure 1-6. These segments should be as small as possible and yet large enough to allow for an easy measurement. The gradation value for each segment is calculated as shown in the illustration, and this value is then squared. An average gradient is computed, and the resultant is divided by the density difference between D_{max} and D_{min}. As a formula, this computation would appear as follows:

$$A = \frac{\text{Average of } (G)^2}{D}$$

where

A = Acutance
G = Gradient
D = Density difference

Remember the value of using acutance as a predictor. Used in conjunction with resolving power, sine-wave response, spread function, and granularity, an acutance value provides a measure of predicting such things as image quality and emulsion or processing behavior patterns. Since this is a mathematical expression, it is completely objective.

Exercises (668):

1. How do you measure acutance?

2. List the physical characteristics of light as it passes over a sharp knife edge.

3. Define acutance.

4. If a system produces high acutance in the laboratory, what can you predict about the system in actual use?

1-3. Granularity

One of the prime factors in image evaluation—one which affects the ability of a film to successfully record very small images—is "granularity," including, to some extent, the distribution of the grains. Remember that "granularity" is not the same as "graininess," which involves a visual subjective impression. Granularity considers the granular structure of a photographic image and its expression in numerical terms. Since granularity may be expressed in mathematical terms, it is quite definitive.

669. State the importance of granularity as it relates to the intelligence community and the different kinds of images recorded by the Air Force.

Importance of Granularity. You may think that microscopic examination of photographic images is unnecessary. However, consider the various types of images that are recorded by the Air Force. These include photographs involving (1) distances from aerospace to ground, (2) those from ground to aerospace, (3) those made for research and development assessment, and (4) those having the extremely fine images necessary for engineering, aeromedical, and analytical analyses.

The importance of minute images should become apparent if you consider just one example. Assume that the camera and the subject are positioned 300 miles apart. The size of the bits of information we are interested in will be small beyond imagination. Let us begin by thinking in terms of conventional photography for a moment and consider a subject that measures 50 feet in width. If this object is photographed from a distance of 5 miles (26,400 feet), which is not uncommon, using a camera with a 24-inch focal length lens, the scale would be 1:3200. This would give an image of about 0.045 inch. Now consider the size of the image if the same camera is moved to a position 300 miles from the same subject. The scale becomes 1:792000. This would give an image of about 0.00076 inch.

Even if the focal length were increased four times the original value, or to 96 inches (which might be feasible), the scale would drop to 1:198000, and the image would increase to about 0.003 inch. Can you see—thinking of this comparison—why grain becomes important in relation to the intelligence information that can be obscured if grain exceeds the minimum size attainable?

Exercises (669):

1. Why is the granular structure of a photographic image of importance to the intelligence community?

2. List the various types of images recorded by the Air Force.

670. State how graininess ratings are made, the process of comparative graininess and rating, and give the significance to graininess rating of the blending magnification method.

Grain and Image Quality. When an optical system exposes an image on a photographic material, a certain amount of image-quality degradation occurs due to the scattering of image-forming light within the emulsion. When the photographic material is developed, the image quality is further degraded by the addition of an overall noise component (noise is taken in the general sense as a random unpredictable signal that tends to obscure small signals). This noise component is termed the graininess of the photographic material.

Graininess is attributable to the heterogeneity of the developed photographic material. For example, the image of a uniformly exposed-and-developed silver halide material consists of a large number of randomly arranged small silver grains. At moderately high viewing magnifications, the distribution of combinations of these grains both laterally and vertically through the image layer is seen as slight heterogeneities. The psychophysical impression of nonuniformity that these heterogeneities produce is called graininess.

There is much experimental evidence that graininess reduces image quality, especially when recognition of small image details is of prime importance. The measurement of graininess, therefore, is a very important parameter in evaluating photographic image quality.

Measurement of Graininess. Because graininess is a subjective impression, ratings of graininess must be made with the human eye as the detecting device. Comparative ratings are made by simply viewing two or more different materials side by side at a constant magnification. Assigning graininess values is more absolute with the blending method, where the observer is asked to determine the minimum viewing distance or the viewing magnification at which the heterogeneities of the photographic deposit appear to just barely blend together. The blending magnification method is most significant for rating graininess, since the method of measurement closely corresponds to real viewing situations; i.e., the practical photographer is usually interested in the maximum enlargement that he can make from a negative without having graininess become objectionable.

Exercises (670):

1. What is the graininess in the developed photographic material attributed to?

2. Define graininess.

3. How are graininess ratings made?

4. Briefly explain comparative ratings of graininess.

5. Why is the blending magnification method significant for rating graininess?

671. Tell what, in photographic material, the perception of grainess depends upon, clarify the importance of the size of the microdensitometer, and identify the label for the process when granularity is computed and the aperture size is considered.

Granularity Measurement. To overcome the shortcomings inherent in the subjective measurement of graininess, many attempts have been made to find a purely physical method which correlates well with the psychophysical determination of graininess. "Granularity" is the generic term coined for such physical evaluation methods.

One of the most useful methods of establishing granularity is through the use of a microdensitometer. The perception of graininess or granularity depends upon microscopic light fluctuations in the processed photographic material. When the photographic material is scanned by a microdensitometer, equipped with a small aperture, these transmission fluctuations appear as vertical fluctuations with varying amplitudes on the microdensitometer trace. Note that the size of the microdensitometer aperture is very important. Figure 1-7 shows three traces across the same area of an emulsion, using three different aperture sizes. Inasmuch as the size of the aperture affects density fluctuations, it must be considered in the calculations. As you can see in the illustration, the large aperture averages the grain size, so that the trace is practically a straight line. As the aperture becomes smaller, the density fluctuations become more prominent. A granularity computation where the aperture size is taken into consideration is known as Selwyn granularity. This type of computation is typified by the following formula:

$$G = SD \times A$$

where:

G = Granularity
SD = Standard deviation (RMS) of the density fluctuation at some specific density level
A = Area of scanning aperture

By placing the appropriate figures into the above formula, a granularity index can be obtained for a system with specific parameters. Thus, one system may be compared to another system or to a similar system having different parameters.

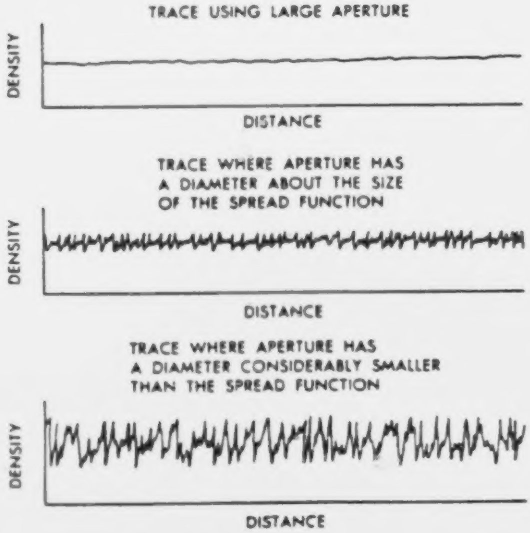


Figure 1–7. Selwyn granularity measurements.

Exercises (671):

1. What is the generic term used for the physical evaluation of the granular structure?

2. What method is used to establish the physical evaluation of the granular structure?

3. What does the perception of graininess depend upon in the photographic material?

4. Is the size of the microdensitometer aperture important? Explain.

5. What is the process called when granularity is computed and the size of the aperture is taken into consideration?

672. Using figures 1-8 to 1-15, state the use of the microdensitometer as related to the measurement of density in the photographic image, and identify the two kinds of apertures, giving the reasons for their use.

Microdensitometer Use. Although more complex in design and construction, most instruments of this type are very similar to conventional densitometers in that both are used to obtain measurements of density in the photographic image; but, the similarity soon ends. A conventional densitometer measures the amount of light passing through a large silver deposit and relates to the "density" of the deposit. A somewhat different procedure is used with the microdensitometer. This precision instrument scans extremely small areas, measures the image, and records the result as a trace on a roll of chart paper. Here, the measurement shows the density of the scanned image plotted against the distance traveled during the scan.

Microdensitometer Application. You have studied that the densitometry is used to evaluate relatively large areas of film by measuring densities present in either black-and-white or color emulsions. The density values were obtained in instruments or microdensitometers that had apertures of 4 mm, 5 mm, or as large as 7 mm. The effect of measuring an area of this size is to average the density fluctuations in the film sample. (The density fluctuations we speak of here are those which are caused by the grain-size-frequency distribution of the sample.) For practical sensitometry, this is desirable, but there are many times when we need to measure the optical densities of extremely small areas. The process of extracting these minute measurements is called microdensitometry.

In microdensitometry, two types of apertures are used. First, *small circular apertures* are effective for measuring the density levels of small areas or for assessing the uniformity of an evenly exposed area. For photometry of minute areas, the aperture selected should be as large as possible without exceeding the size of the image. Second, to measure the distances between various parts of an image, a *slit aperture* is generally used. Occasionally, it might be necessary to make individual density measurements of various portions of an image, but generally most applications require that the image be scanned to yield density measurements as a function of distance traveled. Thus, a microdensitometer should have both slit and circular apertures. To be most useful, a microdensitometer should be able to look at microscopic portions of photographic images and read their optical densities by means of photoelectric sensors. The instrument should also be able to scan at a steady and controllable rate and to record the density readouts on a synchronously moving strip chart.

The ability of a microdensitometer to readout and record density fluctuations occurring in microscopic areas of a photographic image makes it invaluable when measuring photographic effects caused by the granular structure of an emulsion. By evaluating the microcharacteristics of a developed image, you can make a decision as to its sharpness, resolution, and granularity. Moreover, the nature of the scaled trace lends itself to making micromeasurements for a number of specialized applications in aerial photography, photographic instrumentation, and cathode-ray-tube photography, to mention a few.

The measurement of acutance is not possible without a microdensitometer, since this is the instrument used to draw the density-distance curves upon which calculations are based. The first step in making measurements of acutance is to produce a knife-edge exposure in the film to be evaluated. Then the sample is placed in the stage of the microdensitometer and scanned across the edge of the image. This produces the kind of trace shown in figure 1-8. The acutance value of the sample is then calculated according to equation, one given earlier in this chapter.

In an effort to make more objective evaluations of resolving power, this instrument is used to scan the images of various types of resolving power test targets. Sine-wave patterns, such as the one seen in figure 1-9, are used to provide the information for modulation-transfer-function calculations. Also, conventional bar patterns or knife-edge exposures are scanned using slit apertures, and useful inferences are made from the resulting traces (fig. 1-10).

To evaluate the granularity characteristics of an emulsion, a uniformly exposed and developed sample of photographic film is scanned with a small circular aperture. The output is a trace showing random density fluctuations produced by the silver grains in the emulsion (fig. 1-11). From this, the Selwyn, or root-mean-square granularity, value can be calculated.

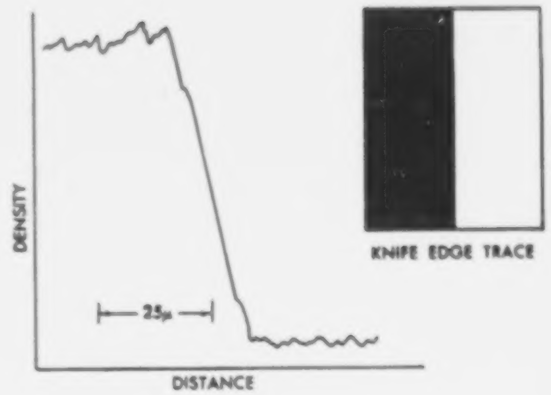


Figure 1-8. Microdensitometer trace of knife edge.

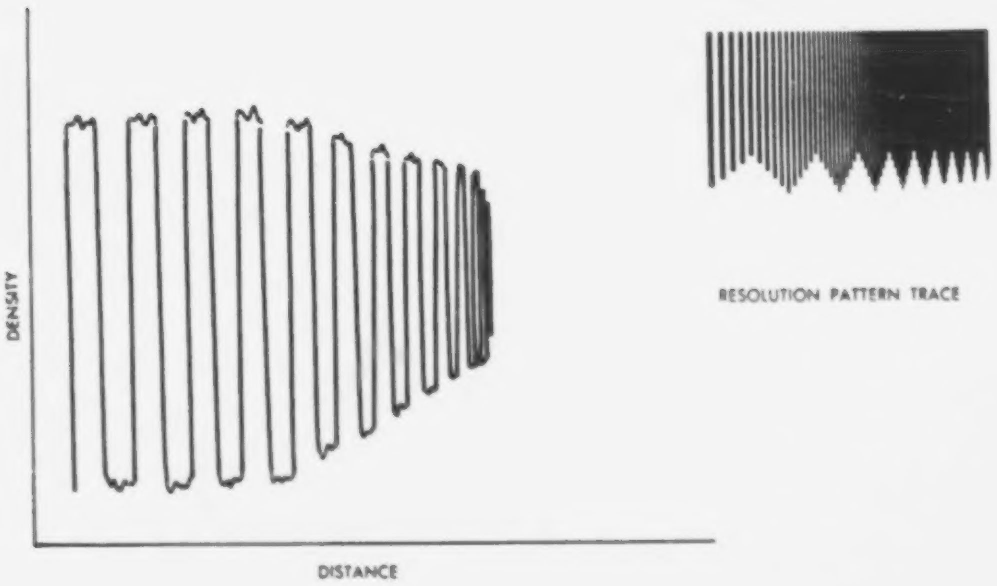


Figure 1-9. Trace of sine-wave pattern.

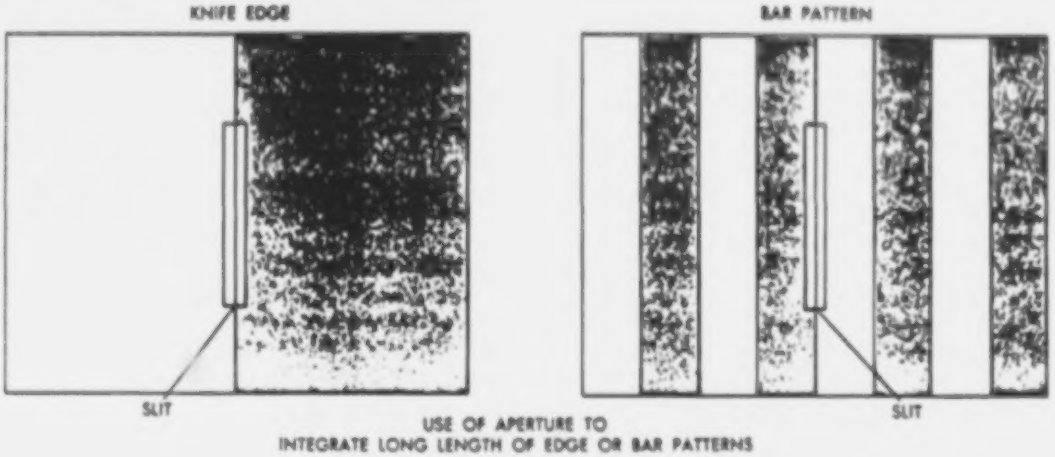


Figure 1-10. Trace of a bar pattern.

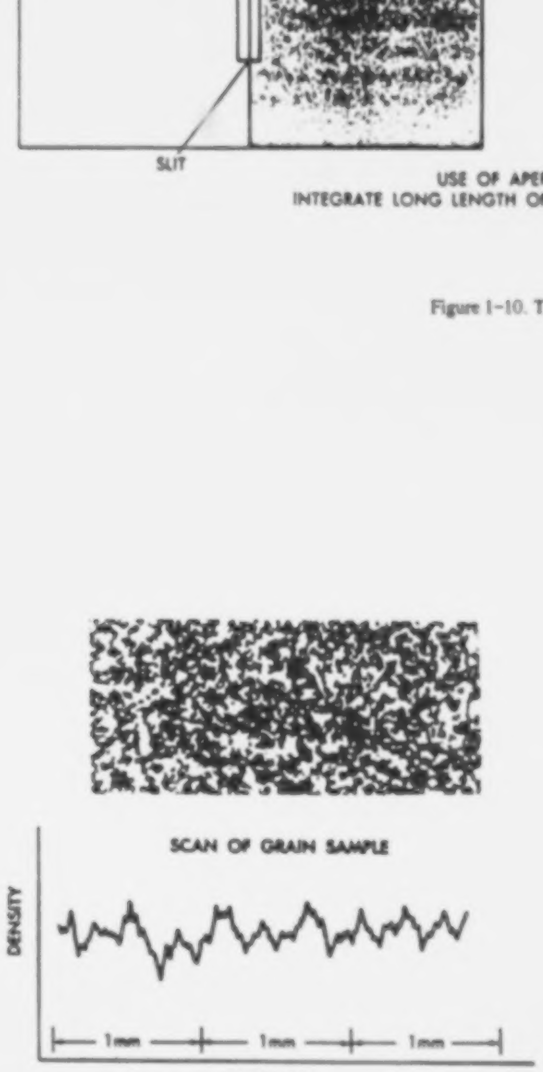


Figure 1-11. Trace of random density fluctuations.

The measurement of star images, such as shown in figure 1-12, is of practical value in astronomical photography to evaluate the intensity of a star. This holds true because the greater the intensity of a star, the larger the point image it forms in the emulsion. Traces across similar point source images are also useful for observing both the Eberhard and Kostinsky effects, both of which are discussed later.

In aerial photography, the microdensitometer is used to make scale measurements of small distances in the image, as seen in figure 1-13. This instrument is also used to evaluate the optimum focus of a camera system or to check changes in land formations, terrain features, and works of man which may occur between reconnaissance flights. The microdensitometer is most useful for evaluating the results of extreme altitude photography where accurate measurements cannot be made by ordinary methods.

Microdensitometers are often used in various aspects of photographic instrumentation. For example, the sketch of an image from a streak-recording camera, shown in figure 1-14, could be scanned, and the photographic density versus the distance from the source of the phenomena could be plotted. Other applications include tracking and ballistics studies.

Records made by cathode ray tube (CRT) photography are evaluated in a number of ways using a microdensitometer. For instance, figure 1-15 shows a CRT line trace that was scanned to give the photometric value of this trace. Also, the instrument is used to measure the distance between transients in a CRT photograph. Photographs of a radar screen are measured using techniques similar to those used in aerial photography.

Exercises (672):

1. Describe how a microdensitometer is used to obtain measurements of the density in a photographic image.

2. Name the two types of apertures, giving the reasons for their use.

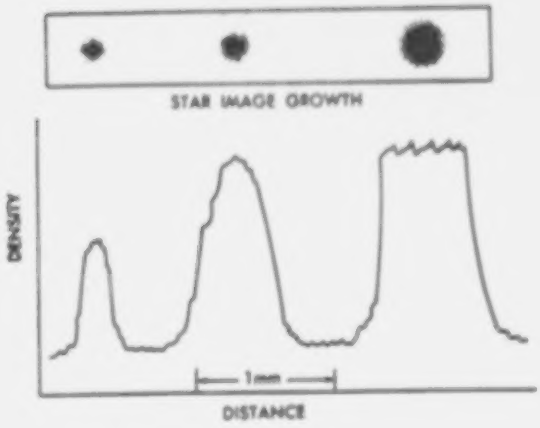


Figure 1-12. Trace of star growth.

673. State the conditions needed to control the dimensional stability of the film and how the dimensional instability of a film can lead to the loss of intelligence data.

Dimensional Stability. You have studied that the prime value of an aerial photograph is the amount of information which is obtained from it. It must therefore have fine grain, high resolution, and edge sharpness, among other requirements. However, if due to the *in*stability of the film or its base, the dimensional aspects change and distort detail, the intelligence value of the photograph may be lost.

You may think of any photograph as being a planar representation of some subject to some scale, the scale being a function of the taking lens and the lens-to-subject distance. Nothing else should be permitted to affect the scale. If you maintain these conditions, the photograph is valuable to anyone who needs to calculate the exact relationship between the subject and the reproduction. Anything that alters the dimensional stability of either the emulsion or its support also alters the exactness of reproduction. Previously, you studied that the chief factors that produce dimensional changes are temperature and humidity.

If the dimensional stability of film is to be controlled, you must closely monitor every variable. To do this, you must control the environment in which the film is processed; and you must control, using all of the means at your disposal, the development storage, and delivery of the product of your laboratory.

Control is not only expensive, but also, it is difficult to maintain. However, where it is essential to hold distortion to the absolute minimum and where the penalties for not doing so are great, you must exercise the greatest possible control.

Exercises (673):

1. How can the dimensional *in*stability of a film cause intelligence information to be lost?

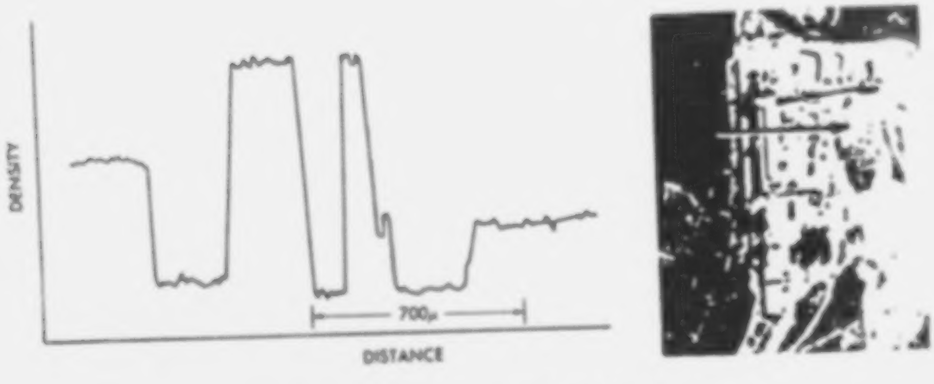


Figure 1-13. Image measurements through a trace.

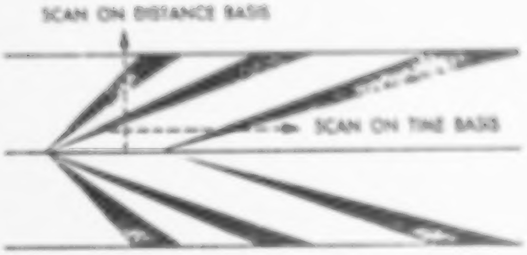


Figure 1-14. Density vs. distance measurement from a trace.

2. How do you control the dimensional stability of film?

1-4. Causes of Exposure Anomalies

While any change in the silver halides or in the emulsion can be termed an exposure effect, we will use the expression to designate any of those changes which are not a part of the normal photographic process. Some of these are controllable and are used sometimes to produce out-of-the-ordinary photographs, while others are beyond the control of the photographer.

674. Specify the probable causes of the Clayden effect, and state how the Gurney-Mott Mechanism provides an explanation.

The Clayden Effect. The apparent reversal which sometimes occurs when a photographic emulsion is first given a short, high intensity exposure followed by a long exposure to light of low intensity is called the Clayden effect. The Clayden effect is not a true reversal effect, since the reversal action is not necessarily present as a result of these exposure conditions. The first high-intensity exposure seems to desensitize the emulsion, so that the second exposure to weak light produces less effect than if the first exposure were not made. That is, the density resulting from the combined exposures is less than the density produced by the weak-light exposure alone, giving the appearance of reversal in the area where the two exposures are superimposed.

In 1903, R. W. Wood, while experimenting with various light sources, found that the effect could be produced in the laboratory using any type of light source, provided the intensity of the initial exposure was sufficiently short. Wood found 1/1000 of a second to be the maximum exposure which would produce the effect, and it was more pronounced when exposures of 1/10,000 of a second were given.

The Gurney-Mott mechanism provides an explanation of this effect. The high-intensity first exposure releases electrons more rapidly than the surface traps can neutralize them. Therefore, most of the electrons migrate to the interior of the grain where they form internal latent images, or subimage nuclei. These nuclei, in turn, become electron traps and compete with those on the surface for the electrons released during the secondary exposure. If the internal nuclei attract enough of the electrons, there may be less total surface image formed by the two combined exposures than that formed by one alone. Thus, the second exposure may produce a greater developable density in the areas not affected by the first exposure.

Exercises (674):

1. What is the probable cause of the Clayden effect?

2. How does the Gurney-Mott mechanism provide an explanation for the Clayden effect?

675. Specify the probable causes of the Villiard effect and the corrective measures.

The Villiard Effect. In 1899, P. Villiard reported a reversal effect with X-ray films which were given an exposure to light following the X-ray exposure. This effect was thought at first to be associated with the Clayden effect, but later investigations found similarities between the Villiard effect and solarization.

The experiments of Arens and Eggert, using different types of emulsions, indicated that if the second exposure was sufficiently intense, an increase in density may precede the decrease in density.

A reversal effect occurs when the film is exposed, first, to X-rays and, second, to light, though it is usually not produced if the order is reversed. In the instances when exposing first to light and then to X-ray does produce a reversal, the mechanism involved was found to be quite different from that producing the Villiard effect.

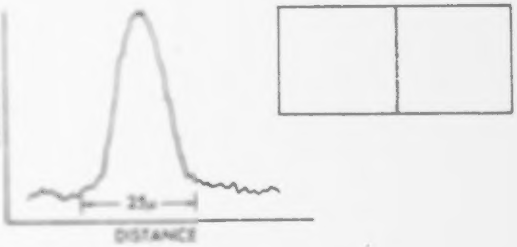


Figure 1-15. Photometric value of a CRT trace.

The Villiard effect was found to be dependent upon temperature, and the lowering of the temperature by the same amount for both exposures causes the effect to disappear. In fact, it is no longer observable for temperatures below −50° C.

Evidence that the Villiard effect is similar to solarization is further supported by the discovery that neither will occur if the emulsion is bathed in a solution of sodium nitrate before exposure to white light.

Exercises (675):

1. What causes the Villiard effect?

2. What corrective action can be taken to minimize the Villiard effect?

676. State the probable causes of "solarization," whether all emulsions are capable of solarization, and corrective measures.

Solarization. The term "solarization" was first used to describe the cause of the bronze appearance of the shadows produced on printing-out papers by great overexposure. Now, however, it is used in conjunction with the reversal effect in film owing to excessive exposure. When silver halides receive an exposure greater than that necessary to produce maximum density, the developable condition of the halides is lowered or even destroyed. This effect is not the same for all emulsions. That is, some do not solarize readily, while others exhibit a marked tendency toward solarization. In fact, some emulsions, upon receiving sufficient exposure, will enter a re-reversal stage and once again produce an increase in density. This condition is also called the second negative stage. While it sometimes is possible to produce solarization in some emulsions by accidental overexposure, re-reversal can only be obtained by deliberately subjecting the emulsion to excessively long exposures.

Solarization is produced by an overdose of any kind of radiation which can, under proper conditions, produce a latent image. This includes light rays of all wavelengths, UV radiation, X-rays, and beams of electrons. Also, there is some evidence that solarization is produced by alpha particles and ions.

The effect of development. The nature of development has, it is believed, a great deal to do with the amount of solarization obtained. If the developer contains no silver halide solvent, solarization occurs quite readily, while the presence of strong solvents, such as thiosulfate, may completely destroy the solarization effect. Ordinary developers, containing mild solvents, such as sodium sulfite, will permit solarization if development is not prolonged. However, when the developing time is extended, the solvent action of the sodium sulfite can reduce solarization to a marked degree.

Rehalogenation. Solarization is reduced, or even eliminated, when halogen acceptors are present during exposure. Thus, it is thought that solarization is probably associated with a rehalogenation of the latent image. In the usual silver bromide emulsion, for instance, it is likely that when exposure is not excessive, the bromine formed is removed as it reacts with the gelatin at the surface of the halide, thus preventing any appreciable amount of rebromination. However, when exposure is excessive, more bromine is released than can react with the gelatin, and some of the bromine attacks the latent image. If the latent image nucleus becomes engulfed by the bromine, it will not respond readily, if at all, to the action of the developing solution.

The effect of intensity. Another factor influencing solarization is the intensity of the exposing radiation. Experiments have shown that, on some emulsions, exposures made at high intensities induced a more pronounced degree of solarization than did those made at low intensities. Also, it was found that a smaller total exposure was needed to produce reversal when high-intensity exposures were used.

The effect of temperature. Solarization seems to be affected by temperature to a significant degree. Experiments have shown that successive reductions in temperature first cause the maximum density to decrease and then cause the peak of the characteristic curve to shift toward longer exposures. Ultimately, lowering the temperature tends to completely prevent the occurrence of solarization. There is a notable exception to this. Recently, some experiments have shown that one emulsion exposed at −196° C. solarized strongly, but since further experiments have not been reported, this cannot be taken as being conclusive.

Exercises (676):

1. What causes solarization?

2. Are *all* emulsions capable of solarization? Explain briefly.

3. What type of radiation produces solarization?

4. What effect does development have on solarization?

5. What happens when halogen acceptors are present during exposure?

6. What effect do high intensities have on some emulsions?

7. What effect does temperature have on solarization?

677. State the probable causes of the Herschel effect, the Abney's oxidation theory, and identify and distinguish between the two kinds of reversal phenomena.

The Herschel Effect. The photographic effect produced in an emulsion by exposure to blue light may be cancelled if the emulsion is subsequently exposed to red light before development. This destruction of the latent image is known as the Herschel effect. It was named for Sir John Herschel, who published his observations of this phenomenon in 1839–40. Herschel discovered that this effect was more pronounced when an excess of potassium iodide was present. This indicated to Abney (who continued this investigation) that silver, when exposed to light in the presence of silver nitrate, releases iodine which would bleach the silver produced by the original exposure. Experimenting further, Abney exposed collodion emulsions to light, treated them with oxidizing agents (potassium bichromate, nitric acid, permanganate, or hydrogen peroxide), and then exposed the emulsion to the spectrum. Abney found that the image, from the beginning of the red portion and extending well into the infrared region, was destroyed. Abney considered that oxidation was a determining factor and that oxidation was accelerated by the red light. Leszynski, on the other hand, concluded that the oxidation theory was doubtful. He offered a hypothesis of a dispersion, or redistribution of the latent-image silver nuclei by infrared exposure.

In 1929, Trivelli carried out a quantitative investigation of the Herschel effect in order to determine how the amount of exposure of blue light and infrared radiation exerted its influence. He found that the ratio of the reversed density to the initial density was maximum at some intermediate preexposure value, and that development had some small effect. Trivelli concluded that materials which desensitize for the latent image process, sensitize for the Herschel effect.

Carroll produced spectrograms which indicated that the region of reversal is related to the absorption properties of the desensitizing dyes. Carroll, as well as other workers using desensitizers, found strong evidence to support the oxidation theory.

It is believed now that two types of reversal phenomena exist. One is due to a process of oxidation caused by the light absorption of the desensitizing dye, and the other is a reversal effect brought about by the direct action of light upon the latent-image nuclei.

Exercises (677):

1. What is the Herschel effect?

2. What is Abney's oxidation theory?

3. Identify and differentiate the two types of reversal phenomena.

678. Define the Sabattier effect and find the probable causes of it.

The Sabattier Effect. If a film is normally exposed, developed, and washed (not fixed), and is then given a uniform exposure and developed again, a reversal of the original image will occur. This effect was discovered in 1850 by Sabattier and is thus called the Sabattier effect in his honor. Depending upon the magnitude of the second exposure, the reversal may be partial or complete. This is a technique used by photopictorialists to produce unusual effects and is sometimes erroneously called solarization or partial solarization. With partial reversal, increasing the first exposure causes decreasing density values until a minimum density is reached; then the density increases again. Because of this, the areas receiving the heaviest initial exposure may be bordered by somewhat transparent bands which separate them from lightly exposed areas. One explanation of the Sabattier effect is that the negative image produces a screening effect in the subsequent exposure of the silver halides present in the emulsion. The second development is then supposed to produce a positive image. However, reversal effects have resulted from exposures made through the base of the film where there was no screening effect. Consequently, this explanation is not conclusive. Another explanation is that the Sabattier effect is due in part to desensitization by metallic silver produced during the development of the negative image and to printing of the negative image onto the remaining silver halides.

Exercises (678):

1. What is the Sabattier effect?

2. Give the causes of the Sabattier effect.

679. State the probable causes of the Albert effect and the conditions in which Luppo-Cramer got the same results.

The Albert Effect. In 1899, Albert determined that if a wet collodion plate is given an excessive exposure and then bathed in nitric acid, washed, reexposed to diffused white light, and developed, a positive image may be obtained. This is known as the Albert effect. Later, in 1909, Luppo-Cramer found that the same result could be obtained using silver bromide gelatin plates bathed in chromic acid or ammonium persulfate. His explanation was that these oxidizing solutions remove only part of the photolytic silver produced by the initial exposure, and the rest is present as an absorption complex with silver bromide. He believed that this complex could resist attack by chromic acid and would be less sensitive to light or less reactive to developer than the original silver bromide.

Exercises (679):

1. What is the Albert effect?

2. Under what conditions did Luppo-Cramer obtain the same results as Albert?

3. What was Luppo-Cramer's explanation for the positive image?

680. Explain the mechanism that operates in the internal image reversal.

Internal Image Reversal. In 1944, Arens and Eggert, while trying to produce useful direct positives using the Sabattier effect, felt that the results were unsatisfactory because of the high fog produced when the first exposure's negative image was developed. They responded that the fog could be reduced by using an emulsion which, when given normal exposure and development, would produce a maximum density of just 0.5. Such emulsions, if exposed while they are immersed in developer, give a density of 2.0 or higher, which is normal because of their silver content. Since the areas received the initial exposure in the dry state responded to a much less degree to the second exposure, continued development gave a reversal image. The negative image developed at the same time had so little density and contrast that it did not interfere with the final positive image, and the final result showed a reversal with a minimum density much lower than that which is normally obtained with the Sabattier reversal.

While, at first, this seems to be a Sabattier reversal, later investigations suggest that quite another mechanism is operating. Investigators used special emulsions which, on exposure in the dry state, formed a latent image in the interior of the grains. These emulsions produced flat curves with surface latent image but gave high density and contrast with internal developers. If they were then treated so that they are able to form surface images, a reversal was formed by subsequent exposure and development. It is apparent that this reversal depends upon the sensitivity of the first exposed grains being lowered by the formation of the internal latent-image nuclei. Thus, this is an internal image effect which more closely resembles the Albert reversal rather than the Sabattier effect.

Exercises (680):

1. Explain the mechanism that operates in the internal image reversal.

2. What result seems, but isn't, the Sabattier reversal?

1-5. Causes of Processing Anomalies

Under this general heading, we will try to include most of the things that can happen to a gelatin emulsion during the process of developing an image. Most of the so-called processing effects may be termed adjacency effects. This term describes what may take place in a film when two juxtaposed areas are developed after receiving exposures of different magnitude. However, there are other processing effects which occur when gelatin is wet and dried and when film and developers are set in motion during development.

681. Using figure 1-16, state why most processing effects are labeled "adjacency effects," state the probable causes of adjacency effects, and identify what the rate of diffusion is dependent upon.

Adjacency Effects. As already stated, most processing effects can be broadly labeled as adjacency effects, since adjacent areas of different densities are usually involved. These effects are generally thought to be caused by the chemical changes produced in the developer by the development process, and they increase in proportion to the amount of silver developed. Since some of the byproducts of development tend to accelerate the process, and some tend to retard it, adjacency effects are also spoken of as being acceleration or retardation effects.

In both instances, reaction products diffuse out of the emulsion into the developer from the point they are produced. The rate of diffusion is dependent upon (1) the nature of the reaction products, (2) the physical character of the emulsion, and (3) the temperature of the processing solution. During development, reaction products are formed in the emulsion and diffuse outward into the developer, as shown in figure 1-16. These byproducts of development have a tendency to collect on the surface of the emulsion, making it difficult for those still forming to become assimilated by the developer (fig. 1-16). Obviously, for the reaction products to continue to leave the emulsion, those which collect on the surface must be removed. This is generally accomplished by agitating either the film, the solution, or both. The rate of assimilation of reaction products increases as agitation increases until such time as the reaction products are removed as fast they emerge from the emulsion. During practical processing with proper and sufficient agitation, large quantities of reaction products are dispersed through the developer solution and will effect its performance. However, the effect is gradual, and comparatively large quantities of reaction products are assimilated before their presence can be detected sensitometrically.

Exercises (681):

1. Why are most processing effects labeled "adjacency effects"?

2. What causes the adjacency effects?

3. Upon what is the rate of diffusion dependent?

4. Trace the reaction products during development.

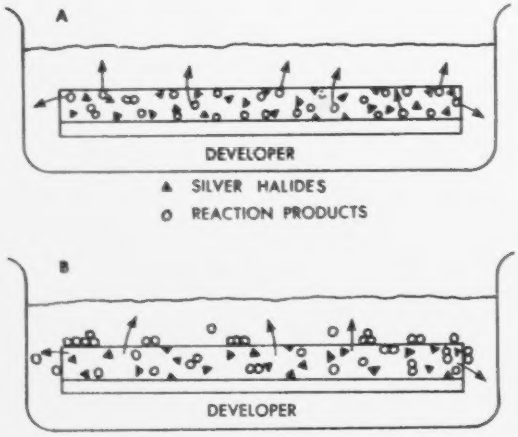


Figure 1–16. Diffusion of reaction products through emulsion.

5. How are reaction products removed from the surface of the emulsion?

682. Using figures 1-17 and 1-18, state the probable causes of the retardation effects, and identify by term the increase in density at the edge of a dark area and the decrease in density at the edge of a light area.

Retardation Effects. When the reaction products hold back the rate of development and are confined within and on the emulsion, the adjacency effects which occur are called the border effect, fringe effect, Eberhard effect, and Kostinsky effect, respectively.

Border and Fringe Effects. In a negative having a dark area adjacent to a light area, the edge of the dark area at the boundary may be denser than the rest of the dark area, and the edge of the light area at the boundary may have less density than the balance of the light area (fig. 1-17). The increase in density at the edge of the dark area is known as the border effect, and the decrease in density occurring at the edge of the light area is referred to as the fringe effect.

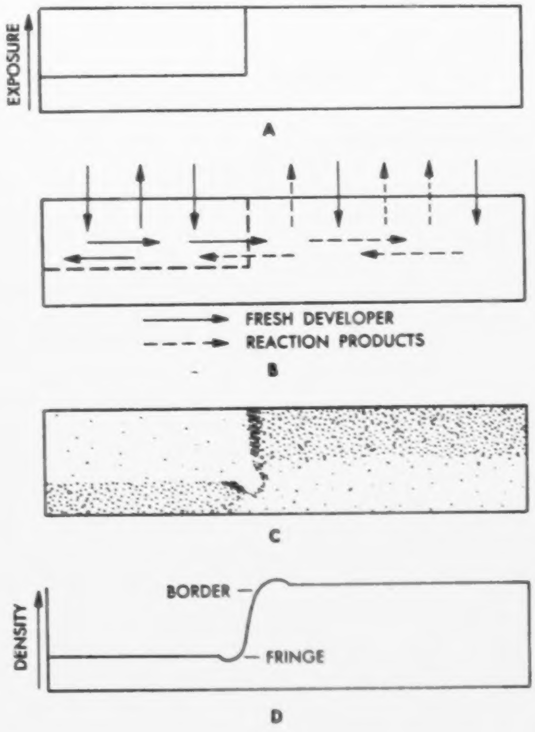


Figure 1–17. Border and fringe effects.

Both together are commonly called edge effects. Because the edge effect sometimes has the appearance of a line, it is also known as a Mackie line.

The occurrence of border and fringe effects requires the exposure conditions represented in figure 1-17,A. There must be a sharp boundary between the heavily and the lightly exposed areas. During the development of a sample exposed in this manner, the developer has little work to do in the lightly exposed area and, consequently, gives out few reaction products. However, the developer in the heavily exposed area becomes exhausted rapidly and produces large quantities of reaction products. Examining figure 1-17,B, you can see that fresh developer can diffuse through the emulsion from the light area to the dense area and exert more effect on those exposed halides adjacent to the border. This fresh supply of developer tends to increase the density in that particular region. Conversely, the reaction products which diffuse from the dense area to the light area will retard development at the border region. The results are as shown in figure 1-17,C, and 1-17,D.

A microdensitometer trace across a knife-edge exposure graphically portrays the border and fringe effects. Figure 1-18 illustrates a representative trace with the density of the image versus the distance on the image. As the microdensitometer moves across the image toward the geometric boundary between the high and low density areas, the density is seen to increase from normal density (Dnor), to a sharp peak at maximum density (Dmax), then density drops abruptly to a minimum density (Dmin), and then rises until the uniform density of the lightly exposed area (Db) is reached.

In 1930, Valenkoff studied the border effect and suggested that the relative border effect be defined as

$$\frac{Dmax - Dnor}{Dnor}$$

This was found to agree very well with the observed border effect, but, when the same thinking was applied to the fringe effect, the formula

$$\frac{Db - Dmin}{Db}$$

did not correlate well with the background density. In 1947, Wolfe and Barrows modified the formula for the relative fringe effect to

$$\frac{Db - Dmin}{Dnor}$$

which correlates more reasonably with background density.

Exercises (682):

1. What are the probable causes of the retardation effects?

$$\frac{Dmax - Dnor}{Dnor}$$

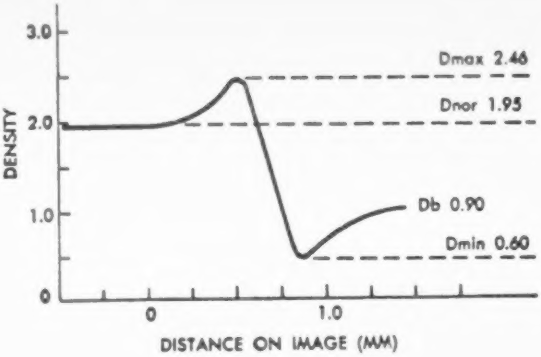


Figure 1-18. Microdensitometer trace across knife-edge exposure showing border and fringe effects.

2. An increase in density at the edge of a dark area is known as the __________ __________, and the decrease in density occurring at the edge of a light area is referred to as the __________ __________.

3. What instrument graphically traces a knife-edge exposure?

683. Using figure 1-19, state the probable causes of the Eberhard effect and the experimental evidence about density as a function of image size.

The Eberhard Effect. If, instead of a knife-edge being used, a series of exposures are made through holes of various sizes cut into an opaque mask, this effect has some noticeable differences. The developed images show a higher density through the smaller holes (those having diameters of approximately 4 mm or less) than the images resulting from exposure through the larger openings. In addition, the smaller the image, the greater is the increase in density above that of the surrounding area. The name given to this phenomenon is Eberhard effect. In the Eberhard effect, density is a function of image size. Figure 1-19 represents a microdensitometer trace across images of varying sizes.

Experiments have demonstrated that an aperture of about 0.1 mm produces the maximum density. Smaller apertures than this result in less density, probably because of the loss of scattered light with the image which is not compensated for by light being scattered from surrounding areas.

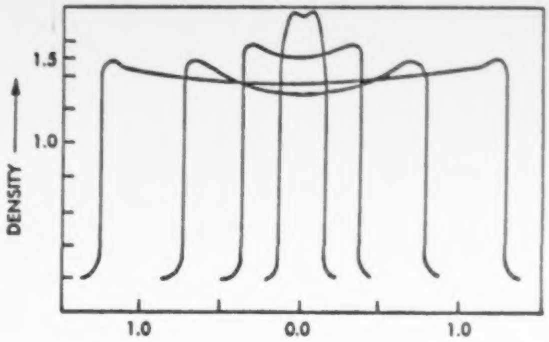


Figure 1-19. Microdensitometer traces illustrating Eberhard effect.

Exercises (683):

1. What are the probable causes of the Eberhard effect?

2. What have experiments demonstrated about the various diameter openings?

684. Using figure 1-20, state the probable cause of the Kostinsky effect, what tends to collect between the two images, and how the effect can be evaluated.

The Kotinsky Effect. The Kostinsky effect occurs when two small images are formed close to each other. Because development in the area between the two images is retarded, a reduced density results (fig. 1-20). Reaction products tend to accumulate between the two images and prevent the development in that area from reaching the desired level. The Kostinsky effect can be evaluated by photographing two point sources of light placed a known distance apart. The distance between the measured separation and the calculated separation gives an indication of the effect.

Exercises (684):

1. What is the probable cause of the Kostinsky effect?

2. What tends to accumulate between the two images?

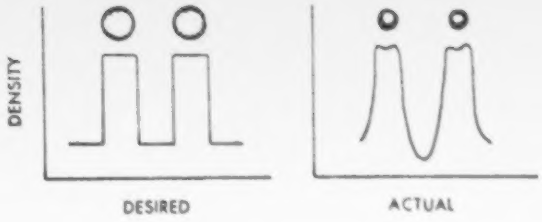


Figure 1-20. Kostinsky effect.

3. How do you evaluate the Kostinsky effect?

685. Indicate the probable causes of bromide and developer streaks, and state how to prevent such streaks.

Bromide and Developer Streaks. Bromide and developer streak effects can be considered as being adjacency effects near the surface of the emulsion. Bromide streaks are formed when the reaction products form an area of high-density flow outward and retard the development in the adjacent area. Developer streaks, on the other hand, are caused by the passage of unused developing agents from low-density areas to areas of greater density, increasing the rate of development in those areas. Since these are largely surface conditions, proper agitation will do much toward preventing their occurrence.

In a letter to the editor of the British Journal in 1918, Mackie presented the idea that bromide and developer streaks resulted from convection currents in the developing solution. He suggested that changes in temperature at the site of development would induce such current. Later, Bullock confirmed the existence of convection currents but gave specific gravity changes as the reason for them. Reaction products have a higher specific gravity than the developer, thus they would tend to move downward through the solution and would affect the film as they moved across it. In 1939, Crabtree and Matthews confirmed the findings of Bullock and added their discovery that the convection current reverses direction when the film is rinsed in water before development. As a consequence, the streaks move upward. The formation of bromide and developer streaks is affected by the type of emulsion and developer involved, the configuration of the image, the density difference, and the amount of agitation given.

Exercises (685):

1. What are the probable causes of bromide and developer streaks?

2. What can you do to prevent the occurrence of bromide and developer streaks?

686. State the probable cause of development mottle and how it can be avoided.

Development Mottle. If an emulsion is given a uniform exposure and allowed to lie stagnant in a horizontal position in the developer, mottle may result. The reason for this is that the diffusion of fresh developer and reaction products within the emulsion takes the form of convection currents. In an unagitated situation, these currents follow slow, random, irregular paths, producing a variation in the rate of development, resulting in variation in densities. This condition can be avoided if proper agitation is given during processing.

Exercises (686):

1. What is the probable cause of development mottle?

2. How can development mottle be avoided?

687. State the probable cause of directional effects and where they are most likely to be found, and summarize whether or not the relative position of the step wedge densities passing through a processor affects the directional effects.

Directional Effects. Directional effects, most likely to occur in machine processing, are a special condition of bromide and developer streaks. In processing machines, the travel of film is in one direction only, and unless steps are taken to maintain adequate agitation of the solutions through which the film passes, the streaks will occur.

In experiments with motion picture film, Crabtree found that the relative position of step wedge densities moving through a continuous processor produced marked differences which could be attributed to directional effects. He made two sensitometric exposures on the film, the second rotated 180° from the first. This oriented one strip so that the end with the maximum exposure was leading and the other, so that the end with the minimum exposure was leading. The D log e curves resulting are shown in figure 1-21. The curve with the dashed line was made from the strip with the high exposure leading, and the curve with the solid line represents the strip with the low exposure leading. The difference between the two curves was taken by Crabtree to be a measure of the directional effect.

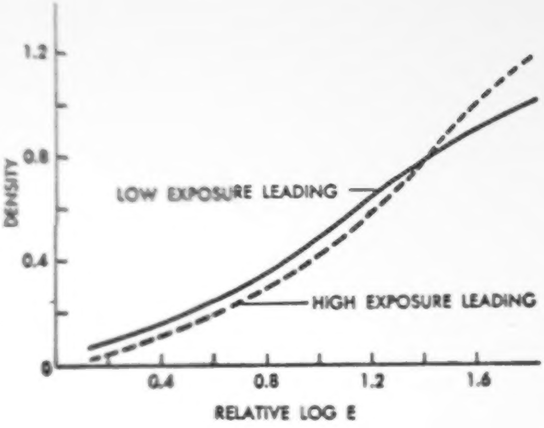


Figure 1-21. Effect of direction on the characteristic curve.

Exercises (687):

1. What is the probable cause of directional effects?

2. Where are directional effects most likely to occur?

3. Does the relative position of the step wedge densities moving through a processor have any effect on directional effects? Explain.

688. State the probable cause of the acceleration effect in a formaldehyde-hydroquinone developer and the cause of unwanted acceleration in perforated film.

Acceleration Effects. Not all reaction products of development retard acceleration. As we have mentioned earlier, reaction products known as semiquinones, will accelerate development. In developers containing formaldehyde-hydroquinone, the density of small photographic images is higher than predicted by the sensitometric tests. Apparently the semiquinone reaction product accelerates development. The formaldehyde acts as a sulfite buffer which maintains an optimum sulfite ion concentration. The sulfite ion concentration acts as a buffer to unite with the semiquinone to form a stable, inert complex.

Exercises (688):

1. What is the probable cause of the acceleration effect in a formaldehyde-hydroquinone developer?

2. What causes the unwanted acceleration in perforated film?

689. State the probable cause of the fogging effect, and specify the activity of hydrazine or its derivatives.

Fogging Effects. In attempts to increase speed and gamma, chemicals such as hydrazine or its derivatives are sometimes added to developers. The reaction products in a developer thus modified have a localized fogging effect in the vicinity of the normally developed, exposed grains. The hydrazine is believed to combine with semiquinones to form fogging agents which are able to reduce unexposed silver halides. These fogging agents are short lived, and their effective action probably does not extend beyond distances of about 0.1 mm from the point of their origin.

The development of the unexposed grains lying near the exposed ones is called infectious development. This phenomenon resembles that resulting from the use of additions (such as formaldehyde) which give reaction products that are quite different. For instance, the effect obtained from developers whose byproducts are accelerators disappears when the developing time is lengthened; but the effect produced by developers whose byproducts are fogging agents becomes greater as developing time is increased. The products generated by the addition of hydrazine develop unexposed silver halides, while the products generated by formaldehyde merely stimulate the development of exposed grains and have no effect upon the unexposed grains.

Another form of infectious development occurs when extruded filaments from developing grains accidentally contact nearby grains and transfer their developability. It is probable that grains lying within 1 micron from a developing grain may become affected in this manner.

Exercises (689):

1. Hydrazine or its derivatives in a developer does what to the speed and gamma of the film?

2. In exercise 1, to what can you attribute this action?

3. What forms the fogging agent?

4. What is the life of a fogging agent?

5. What do you call the development of the unexposed grains in the vicinity of the developing exposed grains?

6. Compare the effects of the acceleration and fogging agents produced by the development process.

7. What causes one exposed grain within a clump of grains to transfer its developability to its neighbor?

690. Using figures 1-22 and 1-23, state the probable causes of some developing agents producing reaction products which tan portions of the gelatin and cause them to absorb less water in the untanned portion.

Tanning Effects. Some developing agents produce reaction products which tan portions of the gelatin and cause them to absorb less water than untanned portions. For this reason, a developed sample placed in an aqueous solution absorbs water and swells to a degree governed by the tanning of the gelatin. Because the amount of tanning products present in the gelatin is proportional to the quantity of silver produced, it follows that this swelling is a function of image density. As the emulsion dries, the high-density areas, tanned to a greater extent, dry more rapidly than the low-density areas. The high-density areas shrink and draw the still damp flexible areas toward them. The shifts in emulsion thus produced are called gelatin effects. The changes which occur in the thickness of the emulsion layer are seen in relief on the surface. Also, shifts in the planes of the emulsion are seen as changes in the size and position of the image. The amount and kind of changes depend in part upon the type of developer used and, also, on the size of the image. Gelatin effects seen in Ross' experiments with photographic plates containing star images were named the Ross effect. Figure 1-22 represents photomicrographs of cross sections of star images. These examples of the Ross effect result from images that were developed and fixed but not dried. The image shown in figure 1-22,A, was originally developed in hydroquinone, and those in figures 1-22,B, and 1-22,C, were developed in pyrogallol. Figure 1-22,A, shows, in the vicinity of the image, a slight swelling which results in very little contraction upon drying. In figure 1-22,B, the swelling resulted in a deep depression at the image and a large amount of contraction while drying. Figure 1-22,C, illustrates a rupture occurring between two images. According to Ross, there is a logarithmic relation between image size, or density, and the contraction of the image caused by the gelatin effect. In one experiment, the relation

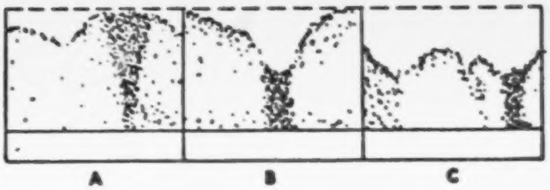


Figure 1-22. Ross effect.

between the contraction of an image 4.5 mm in diameter and density is as shown in figure 1-23,A. Where image densities are about 2.0 or more, the contraction holds quite constant at about 01 mm.

In figure 1-23,B, a curve showing the relation between image diameters and contraction is shown. This curve represents the effect of a series of circular images whose diameters range from 0.1 to 5.0 mm. For images larger than 5.0 mm, there is little change in the reduction of image sizes.

Exercises (690):

1. What happens when a developed sample is placed in an aqueous solution?

2. What happens when a high-density area dries more quickly than a low-density area?

691. State the probable causes of reticulation in an emulsion and one other effect related to an emulsion's excessive swelling and softening.

Reticulation of Gelatin. Although it is not a developing effect, the possibility of reticulation occurring in an emulsion is associated with processing. In the developer, the emulsion is acted upon by the alkali and expands to a marked degree. In the rinse, swelling progresses even further; but in an acid bath, short stop or fixer, the emulsion contracts rapidly. These two opposing actions put a strain on the emulsion, and this is further complicated by the presence of the solid grains of metallic silver forming the developed image. Washing to remove the fixer again produces swelling, which is reversed once more as the emulsion dries. If swelling and contraction occur simultaneously in an emulsion, the strains may be great enough to cause ruptures, particularly if the strains are produced in different areas. If the alternately swelling and contracting areas are distributed over the entire emulsion, a network of ruptures, called reticulation, results. Probably the most common cause of reticulation is the use of excessively warm wash water which produces much more than normal swelling and softening. The reverse strain induced by drying almost invariably results in reticulation.

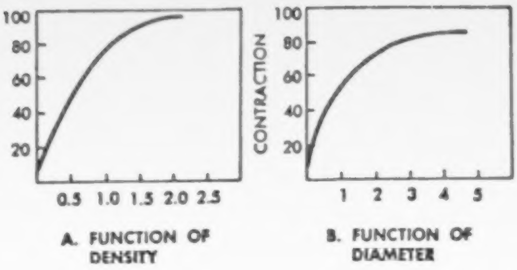


Figure 1-23. Relation between contraction density, and diameter.

Another effect associated with the excessive swelling and softening of an emulsion is the migration of developed silver particles in the reticulated emulsion. This results from the tensions produced which are similar to those occurring during the drying of water spots and which cause the silver particles to aggregate in the drying edge and to move outward from the center.

Exercises (691):

1. When a photographic emulsion is processed, it passes through a series of what kind of solutions?

2. What does the alkalinity of a developing solution do to the emulsion?

3. What happens when the film is transferred from the rinse to the fixing bath?

4. What is the most common cause of reticulation?

5. What is another effect associated with the excessive swelling and softening of an emulsion?

1-6. Specialized Optical Systems

In the field of imagery production photography, conventional camera systems occupy only a portion of the technician's attention. The technician uses many other specialized optical devices, sometimes along with, and sometimes in connection with, camera systems, in the pursuit of the occupation. In this section, we will discuss optical devices used in micro imagery and in measuring instruments.

692. Concerning the role of the eye in the micro system, name the factors determining the size object detectable by the unaided eye, state what you should do to an object to allow the unaided eye to see that object as large as possible, and indicate a simple way of measuring the smallest object an unaided eye can see (fig. 1-24).

Micro Systems. We might use a microscope when we wish to magnify objects which are discernible to the eye; but to see objects, or parts of objects, which are too small to be visible, a microscope is needed. Microscopes are found in many forms, from a simple magnifier to a complex electron microscope. They include so many specialized instruments for specific applications that it would be impossible to list them all, let alone describe them in detail. We will therefore confine our discussion to principles and trust to your ingenuity to apply these principles to whatever equipment you may use. We will begin by considering the role of the eye in the micro system.

Visual acuity. Where no functional defects exist, the size of an object detected by the eye is dependent upon:

- The size of the receptors (rods and cones) on the retina.
- The distance between the object and the nodal point of the eye.
- The angle that the object subtends at the optical center or nodal point of the eye.

Referring to figure 1-24, we can see that the apparent size of the object, O, is represented by the visual angle θ_1, and can be measured trigonometrically. We can see that as the object moves nearer the eye, the angle θ_1, increases to θ_2 and the retinal image, I, also increases. Therefore, in order to see an object as large as possible with the unaided eye, it must be moved as near to the eye as possible. There is, however, a near point, which is the nearest point that the object can still be seen distinctly. The distance of this point is about 10 inches, or 250 millimeters for the normal eye. If we call this distance Dv, the apparent size of our object can be expressed as O/Dv (radians).

A simple method of measuring the smallest object that the unaided eye can see involves making, or purchasing, a series of grids consisting of alternate opaque and transparent lines varying in regular increments from, say, 100 lines per inch to 300 lines per inch. Each grid is viewed by transmitted light of about 10 foot-candles at a distance of 10 inches from the eye. The grid whose lines are just visible is taken as the measure of the minimum detectable object size. Most observers can detect about 260 lines per inch (slightly over 10 lines per millimeter), and this very nearly approximates the accepted visual acuity angle of 1 minute of arc for the human eye.

To enable the eye to see objects smaller than this requires using some optical instrument to increase the size of the retinal image. The magnifying power of such an instrument is the ratio of the size of the retinal image to the size of the object. Thus, magnifying power of the instrument is:

$$= \frac{\text{Visual angle of image}}{\text{Visual angle of object}}$$

Exercises (692):

1. The size of an object detected by the unaided eye is dependent on what factors?

2. In order to see an object as large as possible with the unaided eye, what should you do to that object?

3. What is a simple method of measuring the smallest object that the unaided eye can see?

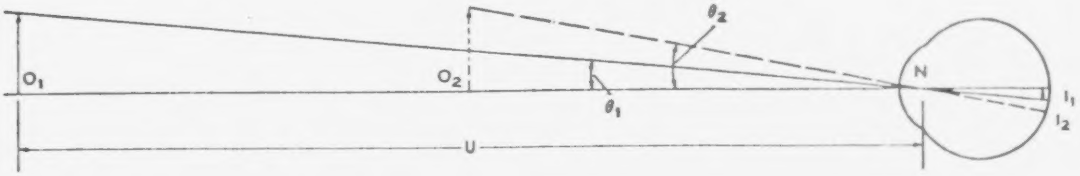


Figure 1-24. Apparent size of an object is affected by its position relative to the eye.

693. Using figure 1-25, state how the compound microscope produces its magnification, how objective lens work, and what happens to the image formed by the eyepiece.

The Microscope. A simple microscope is merely a single, generally short focus, lens used as a magnifier or reading glass. When such a lens is held in front of the eye, a magnified virtual image of an object is seen. This requires that the object be situated inside the focal length of the lens.

The simple microscope is available in many forms and is used extensively in many applications. In addition to hand magnifiers, there are jeweler's loupes, linen testers, and simple comparators consisting of a high quality magnifier equipped with a measuring scale. These simple microscopes all enjoy wide usage and perform a very important service. For precise measurements of microscopic objects, however, the compound microscope is needed.

The Compound Microscope. The compound microscope produces its ultimate magnification by remagnifying a magnified aerial image. The objective lens looks at the object and produces an enlarged aerial image within the tube of the instrument. This image is, in turn, seen by the eyepiece, or ocular (fig. 1-25). The image formed by the eyepiece is enlarged and virtual, and it is this image that affects the retina of the viewer's eye.

Exercises (693):

1. Define the simple microscope.

2. List the different types of simple microscopes.

3. How does the compound microscope produce its magnification?

4. How does the objective lens work?

5. What happens to the image that is formed by the eyepiece?

694. State the two stages of magnification produced by a microscope and what the magnification involved.

Magnification. Since the magnification produced by a microscope is in two stages, it is the product of the power of the ocular and the objective. Thus, if the power of the objective is 10, and the power of the ocular is 5, the magnification of the combination is 50. If the power of each is 10, the combination will operate at 100X.

The magnification of a microscope is limited mainly by the resolving power of its optical equipment. If an object is magnified to the larger image, it will be fuzzy and indistinct. Magnification beyond the ability of lenses to resolve is called empty magnification, because it has exceeded the useful limit in showing detail in the object.

Exercises (694):

1. What are the two stages of magnification produced by a microscope?

2. If the power of the objective is 47 and the power of the ocular is 10, what is the magnification?

695. Concerning the resolving power of a microscope as related to the design of the objective, state what governs the resolving power, how such power is related to the objective's numerical aperture, and how much power can be increased.

Resolving Power. The resolving power of a microscope is governed largely by the design of the objective. An objective which has a large angular cone of light coming from the object has higher resolving power than one which has a smaller cone of light. The resolving power, being governed by the radius of the first dark ring of the Airy disk and the numerical aperture of the objective, is defined by the equation

$$h = \frac{0.61}{N.A.}$$

where h = resolvable separation

$0.61 = \frac{1}{2}$ of constant 1.22

N.A. = Numerical aperture

Since numerical aperture is defined as N.A. = n sin U. Thus, we see that resolving power is inversely proportional to the numerical aperture of the objective.

As indicated by the above formula, resolving power is increased in three ways. In order to decrease the resolvable separation h, we might

- Decrease the wavelength λ.
- Increase the angle U.
- Increase the index of refraction, n.

We can decrease the wavelength, λ, by going to the short end of the spectrum, either by the selection of filters or by the selection of suitable light sources—even into the ultraviolet region.

The angle U is increased within limits, by increasing the numerical aperture of the objective. The 0.95 N.A. apochromat gives the highest value of U. Beyond that, oil immersion methods must be used.

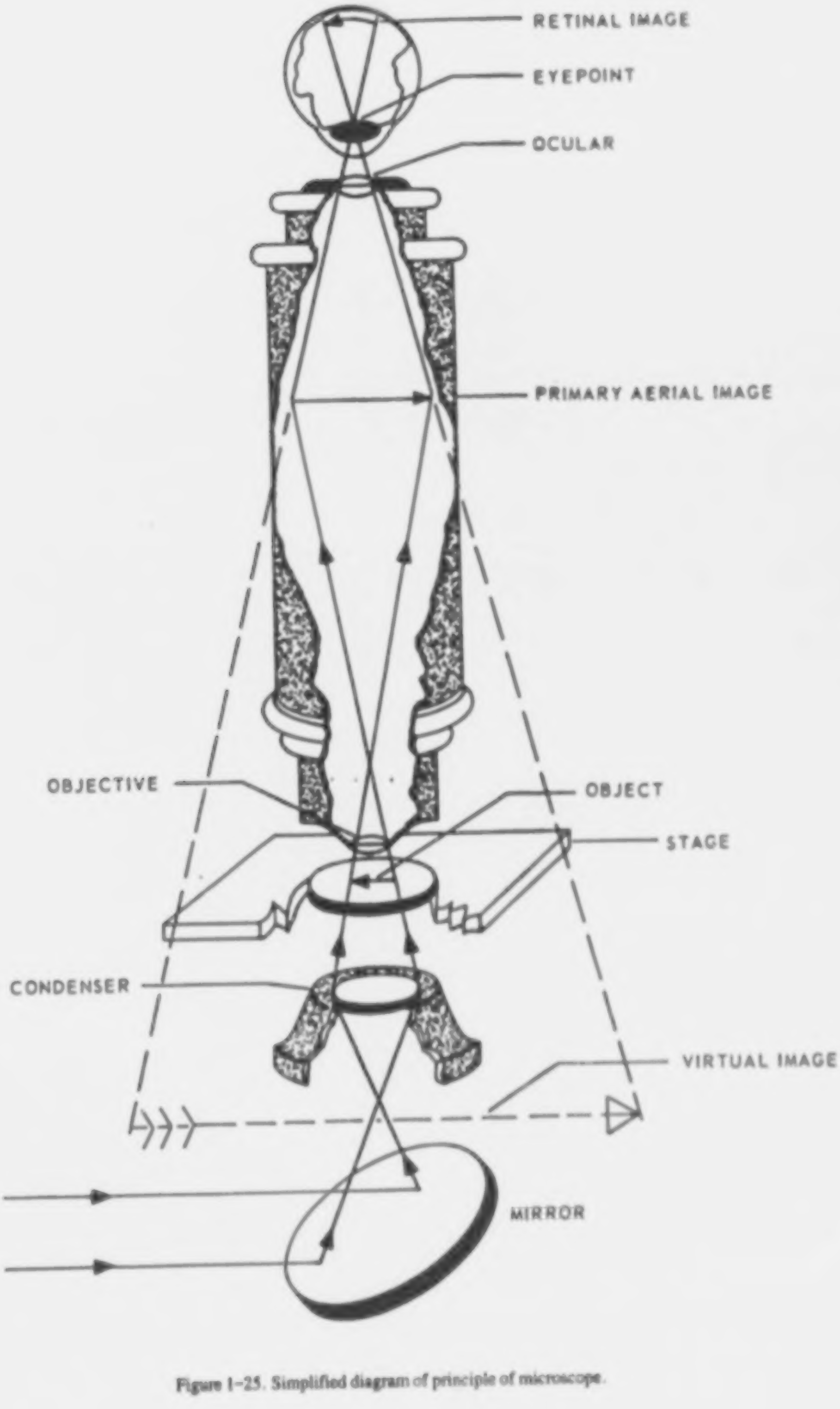

RETINAL IMAGE
EYEPOINT
OCULAR
PRIMARY AERIAL IMAGE
OBJECTIVE
OBJECT
STAGE
CONDENSER
VIRTUAL IMAGE
MIRROR

Figure 1-25. Simplified diagram of principle of microscope.

The use of an immersion fluid with the appropriate objectives is the third way to increase resolving power. The presence of oil in the space between the specimen and the objective increases the index of refraction from 1.00 for air to about 1.52 for oil. In use, the oil occupies the space between the top of the specimen slide and the objective, and sometimes, between the condenser and the bottom of the slide.

Exercises (695):

1. What governs the resolving power of a microscope?

2. How do you relate resolving power to the numerical aperture of the objective?

3. How can resolving power be increased?

696. Using figure 1-26, list the major types of microscope objectives and, of these, identify the one that is most complex and color corrected.

Types of Objectives. Microscope objectives are of three major types: (1) achromats, (2) fluorites, and (3) apochromats. The achromats are corrected for chromatic aberration and perform well at lower powers. However, at higher power, they are lacking because of chromatic and spherical aberrations.

Combining fluorite and glass lenses produces an improved objective, and lenses of this type are known as fluorites.

The aprochromat is the most complex and most highly corrected of the three; hence it is the most expensive. Its use is recommended for the most critical work. Figure 1-26 illustrates the construction of the three types of microscope objectives.

The Americal Optical Company and Bausch and Lomb Optical Company have microscopes on the market using spherical mirrors and the Bouwers concentric meniscus. Most of these are intended for spectrophotometric work in the UV and IR bands.

Exercises (696):

1. List the three major types of microscope objectives.

2. Of the three major types of microscopic objectives, which one is the most complex and color corrected?

697. Using figures 1-27 through 1-31 and table 1-2, list the different types of eyepieces and those having special applications.

Types of Eyepieces. The second state of magnification is produced by the eyepiece; therefore, it is primarily a magnifier which enlarges the image formed by the objective. The most common eyepiece is the Huygenian, named for its designer, Christian Huygens, the Dutch scientist who lived in the 17th century. This eyepiece, shown in figure 1-27, is very satisfactory when used with low-power achromats, but it is lacking in correction for curvature of field and lateral color when used with objectives of intermediate and high power. To compensate for aberrations at the higher powers, the hyperplane and the compensating eyepieces shown in figure 1-28 are used extensively.

The Huygenian lens obtains its correction for lateral color by virtue of two simple lenses. Referring to figure 1-27, the light entering the first lens, called the collective lens, is spread out into a spectrum having red at one limit and blue at the other. The second lens, called the eye lens, is spaced so that the red rays strike it at a point higher than the blue rays. The difference in the angle of refraction causes the red and blue rays to become parallel. The eye, which is focused at infinity, sees the red and blue rays as one color-free image.

The hyperplane eyepiece employs a single collective lens and a doublet eye lens to bring about lateral color correction and does it more effectively than the Huygenian eyepiece.

The compensating eyepiece is essentially the hyperplane using different glasses and lens shapes to increase its compensation for lateral color. This ocular derives its name from the fact that it compensates for the undercorrected lateral color in the objective lens. Figure 1-28 shows the red and blue rays entering the collective lens at different heights and that their spread is reduced by refraction. The doublet eye lens then reduces the spread still more and causes the emerging rays to become parallel.

Eyepieces used for special applications on the microscope include the Ramsden eyepieces, the widefield eyepieces, and the ultraplanes.

Like the Huygenian, the Ramsden eyepiece consists of two simple lenses but differs in the position of its focal plane. The Ramsden's focal plane is located on or just outside of the outer surface of the collective lens (fig. 1-29), while the focal plane of the Huygenian eyepiece lies between the elements. Because of the position of the focal plane, the Ramsden is used extensively when the microscope is employed to make measurements. Measuring scales can be used with Huygenian eyepieces, but the scales lack the sharpness obtained with the Ramsden.

Where an exceptionally wide field of view is required, the widefield eyepieces (fig. 1-30), are generally used. They are suitable for low-power work with such instruments as some stereoscopic microscopes, but their color correction is not adequate for high-power microscopy.

The ultraplanes, while classified as eyepieces, are actually projection lens systems for photomicrography. Their functions are to intercept the image formed by the objective before it comes to a focus and to project it onto

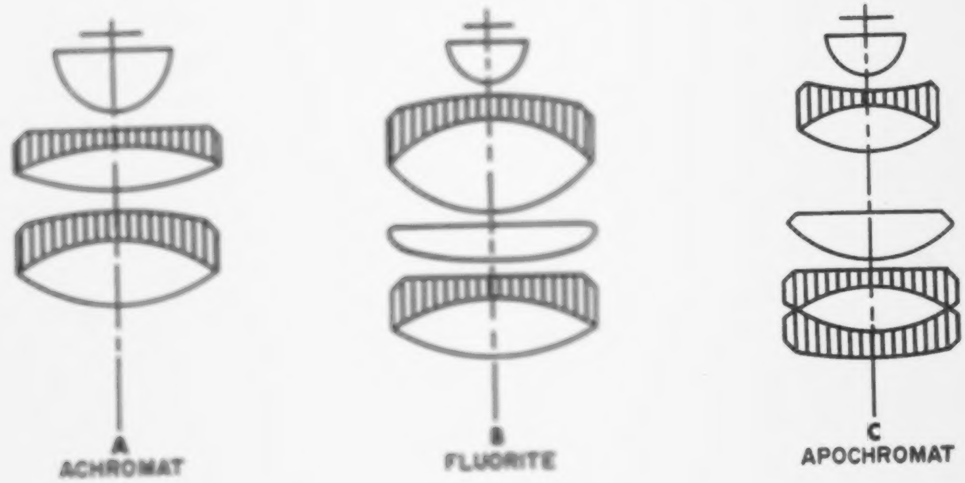

A
ACHROMAT
B
FLUORITE
C
APOCHROMAT

Figure 1-26. Microscope objectives.

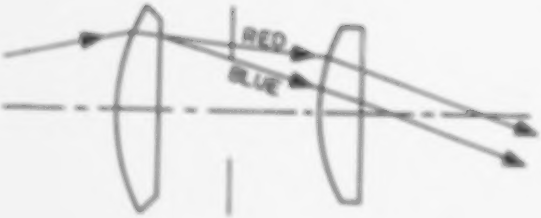


Figure 1-27. Diagram of Huygenian eyepiece.

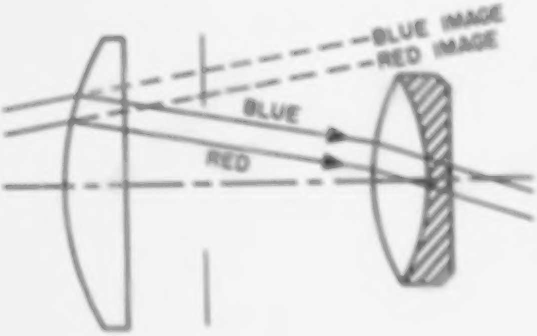

BLUE IMAGE
RED IMAGE
BLUE
RED

Figure 1-28. Diagram of low-power hyperplane and compensating eyepieces.

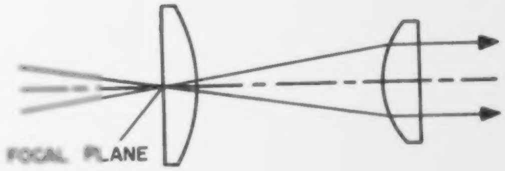

FOCAL PLANE

Figure 1-29. Ramsden eyepiece.

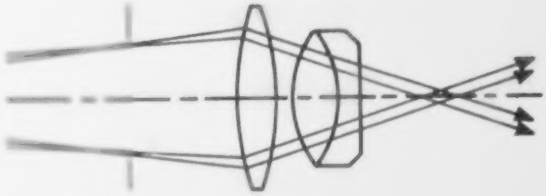


Figure 1-30. Diagram of wide field eyepiece.

the photographic film. The construction of an ultraplane and a diagram of its light path are shown in figure 1-31. In operation, the divergence of the light rays by the negative lens gives some compensation for the curvature of field produced by the objective, thus providing a comparatively flat field at the focal plane of the camera. To correct for lateral color at high-, medium-, and low-power magnification, three separate systems are required. They are designated simply as high ultraplane, medium ultraplane, and low ultraplane.

The objective-eyepiece combinations for most applications are presented in table 1-2.

Exercises (697):

1. List the different types of eyepieces.

2. List the eyepieces used for special applications.

698. List the components of an illumination system.

Illumination Systems. The illumination system, which usually includes a light source, a mirror, and a condenser, is a vital part of the microscope. Without illumination, the specimen can not be seen at all. And with an inadequate or an incorrectly used illuminating system, the performance of even the best microscope will be unsatisfactory. We said earlier that resolving power depends upon the N.A. of the objective. For the objective to perform at its best, we must have a condenser system capable of delivering the largest possible angular cone of light that the objective can admit. This does not imply that the full N.A. of the objective is always illuminated. Most often, the full N.A. illumination is not used. There is no rule of thumb to follow; each specimen must be treated individually to obtain the best results. If the specimen has high contrast and fine detail, nearly full N.A. illumination is needed; but if the object has low contrast, full illumination might wash out the details and should be reduced.

Exercises (698):

1. List the components of an illumination system.

2. Why is the illumination system so vital a part of the microscope?

699. List the components of a condenser system, give the effects of manipulating the iris aperture, and state how full aperture illumination is obtained.

Condenser Systems. The illumination of the N.A. is controlled by the condenser system which includes a substage iris, a condenser, and sometimes, a mirror to

TABLE 1-2

TYPES OF EYEPIECES

Objective	Eyepiece for Visual or Photomicrographic Work	Eyepiece for Photomicrographic Work Only
48.0 mm Achromatic	Huygenian	Ultraplane—Low
40.0 mm Achromatic	Huygenian	Ultraplane—Low
32.0 mm Achromatic	Huygenian	Ultraplane—Low
16.0 mm Achromatic	Huygenian	Ultraplane—Low
8.0 mm Achromatic	Hyperplane	Ultraplane—Medium
4.0 mm Achromatic	Hyperplane	Ultraplane—Medium
1.8 mm *Achromatic	Compensating	Ultraplane—High
4.3 mm *Fluorite	Compensating	Ultraplane—High
4.0 mm Fluorite	Hyperplane	Ultraplane—Medium
1.8 mm *Fluorite	Compensating	Ultraplane—High
16.0 mm Apochromatic	Compensating	Ultraplane—Low
8.3 mm Apochromatic	Compensating	Ultraplane—Medium
4.0 mm Apochromatic	Compensating	Ultraplane—Medium
2.0 mm *Apochromatic	Compensating	Ultraplane—High

*Oil immersion objective.

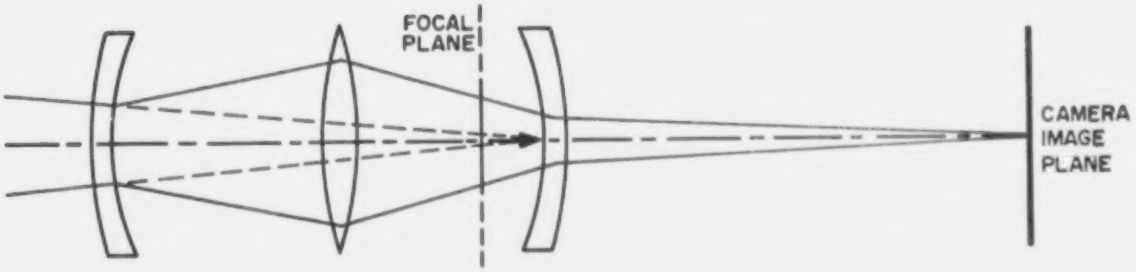


Figure 1-31. Ultraplane.

direct the light from an illuminator. The effect of altering the aperture of the iris can be seen by removing the eyepiece and by peering down into the tube at the back lens of the objective.

If the illuminator used with the microscope is equipped with an iris diaphragm, the substage condenser is adjusted to give a sharp image of the iris on the object plane. The aperture of the iris is then adjusted so that it lies just outside of the field of view of the microscope. Thus, stray light is kept to a minimum and contrast is improved.

Exercises (699):

1. List the components of a condenser system.

2. How can you see the effect of the iris aperture?

3. How do you obtain full aperture illumination?

700. State the purpose of the substage condenser, list the three most commonly used condensers, and clarify separately (1) why the Abbe condenser is used most widely for general microscopy and (2) why the achromatic condenser is recommended for color photomicroscopy (figs. 1-32 to 1-34).

Types of Condensers. The purpose of the substage condenser is to direct a light beam of the desired size onto the specimen slide. Several types of condensers exist, but the three most commonly used are: (1) the Abbe condenser, (2) the variable focus condenser, and (3) the achromatic condenser.

The Abbe condenser (fig. 1-32) is a 1.25 N.A. condenser composed of only two lenses. It is simple, yet it has such excellent light gathering capabilities that it is the one most widely used for general microscopy. Its lack of correction for chromatic and spherical aberrations does not materially interfere with its use for visual observations.

The variable focus condenser (fig. 1-33) is also a 2-lens condenser with a maximum 1.25 N.A. The upper lens element is fixed, and the lower element is movable to permit focusing. Thus it is possible to fill the field of low-power objectives without removing the top element.

The achromatic condenser (fig. 1-34) is corrected for both chromatic and spherical aberrations and operates at 1.40 N.A. Because of its high quality, the achromatic condenser is used extensively for research microscopy and photomicroscopy in color.

Exercises (700):

1. What is the purpose of the substage condenser?

2. List the three most commonly used condensers.

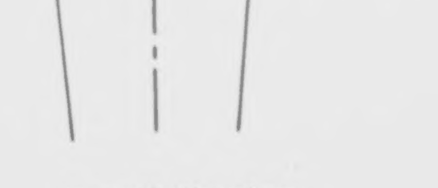


Figure 1-32. Abbe condenser.

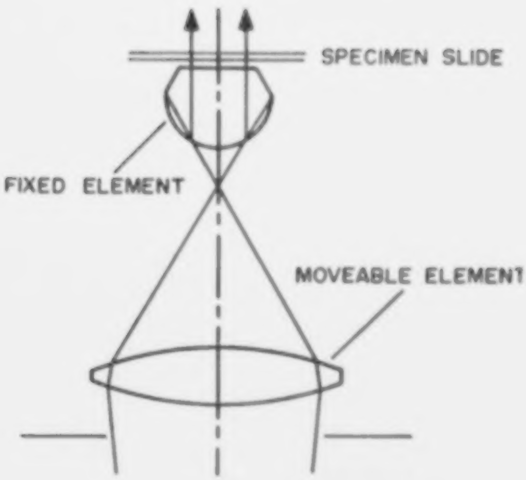


Figure 1-33. Variable focus condenser.

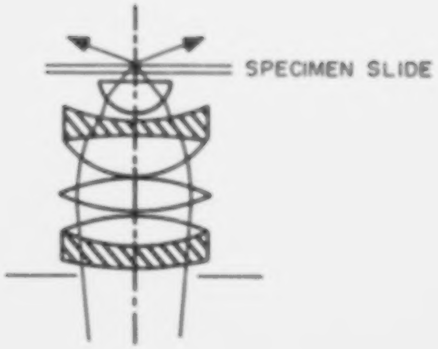


Figure 1-34. Achromatic condenser.

3. Why is the Abbe condenser the one most widely used for general microscopy?

4. Why is the achromatic condenser recommended for photomicroscopy in color?

701. Name the light sources used for microscopy and state the purpose of the illuminator.

Illuminators. The light sources for microscopy, called by the general term "illuminators" are of many varieties. The simplest illuminator is a small incandescent lamp with a reflector behind it and a diffusing glass in front. Others are equipped with more powerful light sources, lenses, diaphragms, and filters or filter holders. Some are attached to the microscope, but most are remote from the instrument. All serve the same purpose, which is to supply illumination to the specimen. There are as many types of illuminators as there are special applications of microscopy, and since information concerning them is available elsewhere, no worthwhile purpose would be served by enumerating types of illuminators in this CDC.

Exercises (701):

1. What is the light source for microscopy called?

2. What is the purpose of the illuminator?

CHAPTER 2

Certification and Calibration of Metrology Equipment

ONE OF THE MOST important attributes of a successful quality control program is the ability to maintain consistent sensitometric control throughout the entire photographic process. Control over the process is achieved through the use of certified photometrology instruments to make accurate quantitative measurements that can be plotted on a control chart for systematic analysis. The certification of these instruments is vital to the effective use of tests and measurements to control the photographic results.

2-1. Basic Metrology Equipment

The basic metrology instruments needed in an imagery production facility are the sensitometer and the densitometer. The functions of these two instruments are taken up first, after which the laboratory correlation procedures are examined.

702. Relate the function of, respectively, the sensitometer and the densitometer.

Functions of the Sensitometer and the Densitometer. The function of the sensitometer is to make precisely controlled photographic exposures to produce step tablets or continuous wedges (gray scales). The densitometer is used to measure the densities of these items and of the actual film itself.

Laboratory Correlation Procedure. An overall laboratory correlation procedure to certify the total laboratory measuring system requires both that the entire photographic process be tested and that the individual metrology instruments be calibrated to a master standard. The purpose of this certification is to detect any significant change in the response of the measuring device; i.e.,

a. Certification of the sensitometer must detect significant changes in the exposure produced by the sensitometer over the useful life of its light source.

b. Certification of the densitometer must determine whether or not the instrument measures density within prescribed specifications. Generally, this is done by comparing current photographic responses with those recorded when the instrument is known to be in control.

A laboratory certification procedure must be designed to include master standards to check the calibration of all measuring instruments. When instrument results do not conform to established standards within prescribed tolerances, the instrument should not be used until it is recalibrated. Instructions for calibration of instruments are generally provided by the manufacturer.

Exercises (702):

1. What is the function of the sensitometer?

2. What is the function of the densitometer?

3. What is the purpose of certification?

4. What should certification of the sensitometer detect?

5. What should certification of the densitometer determine?

703. State how two or more similar sensitometers are tested for accuracy using the correlation test procedure.

Correlation of Sensitometers. In certain instances it may be necessary to compare the relative accuracy of two or more sensitometers. The correlation test procedure is generally employed only when the sensitometers are of the same make and model. In order for this test to be valid, the instruments must have the same type of light source and the same spectral energy distribution. In addition, the instruments must have nearly the same exposure time to insure that reciprocity effects do not bias the data. Sensitometers having slightly different nominal exposure values (that value specified by the manufactures on the sensitometer lamp calibration certificate) can be compared if the difference is primarily due to a difference in the illuminance at the film plane rather than in the duration of the exposure. The correlation test is easiest to evaluate when the nominal exposures at the film plane of the sensitometers under test are equal.

PROCEDURE:

A. Exposure and processing of the test strips.

1. Each sensitometer should be certified by a separate sensitometer certification test before this test is conducted.
2. Turn on the sensitometer lamp controls and adjust them to obtain the proper amperage setting for each instrument. Allow the sensitometers to warm up and stabilize before making exposures (approximately 5 minutes).
3. Insert the proper neutral density and color correction filters into the filter drawer.
4. Cut the required number of film samples from a roll of working control stock. (Absolute control stock need not be used.) The strips should be at least 1 inch wide and 5 inches longer than the length of the sensitometer exposure modulator.
5. Verify the sensitometer lamp amperage setting and expose two film samples on each sensitometer under test. Notch each strip to identify the emulsion side and the toe end.
6. After exposure, age the latent images at room temperature for a period of 1 hour. Properly identify the strips during this time. Include the date, type of test, sensitometer number, and conditions of exposure; i.e., filters used, exposure time, etc.
7. Affix film samples, emulsion side up, to a roll of leader material so that the film samples are carried through the processor. All samples must be oriented parallel to the direction of travel with the area of least exposure (notched end) receiving development first. The strips from each instrument should not be grouped adjacently to each other, but distributed randomly in the array of secured strips.
8. Process the samples with a certified processor, preferably to either a medium or high contrast.
9. Read the densities of the processed strips with a certified densitometer, and average the data from each set of strips to determine the average response curve for each sensitometer.

B. Determination of the differences in the nominal exposures of the sensitometers. Use one of the following three methods:

1. If the instruments have the same nominal exposure; i.e., the calibration certificates indicate that the exposures of the two units are equal:
    - *a*. Plot the average response curve from each instrument on the same graph. The response curves may be plotted with respect to either actual log exposure or relative log exposure.
    - *b*. The estimate of the difference in the exposure of the sensitometers is equal to the log exposure displacement between the response curves (fig. 2-1).
2. If the nominal exposures of the two sensitometers differ and if response curves are plotted with respect to absolute exposure: The log exposure displacement of the response curves is an estimate of the difference between nominal exposure (fig. 2-2).
3. If the nominal exposures of the two sensitometers differ and if the curves are plotted with respect to relative log exposure (step tablet step numbers):
    - *a*. Determine the difference in their nominal exposures (the difference of the calibration certificate exposure value).
    - *b*. Determine the log exposure displacement of the response curves.
    - *c*. Estimate the error in the difference in the nominal exposure value by subtracting the value of step *a* from *b* (fig. 2-3).

C. Evaluation.

1. If the estimated difference is less than the control limits (the inherent variability of the test procedure is approximately ±0.02 log E), the calibrated exposure values of the sensitometers are considered to have good agreement.
2. If the estimated difference is greater than the test control limits, the entire test procedure should be repeated. If the retest also indicates that the exposure error is greater than the test control limits, the instruments are considered to have poor agreement.

Exercises (703):

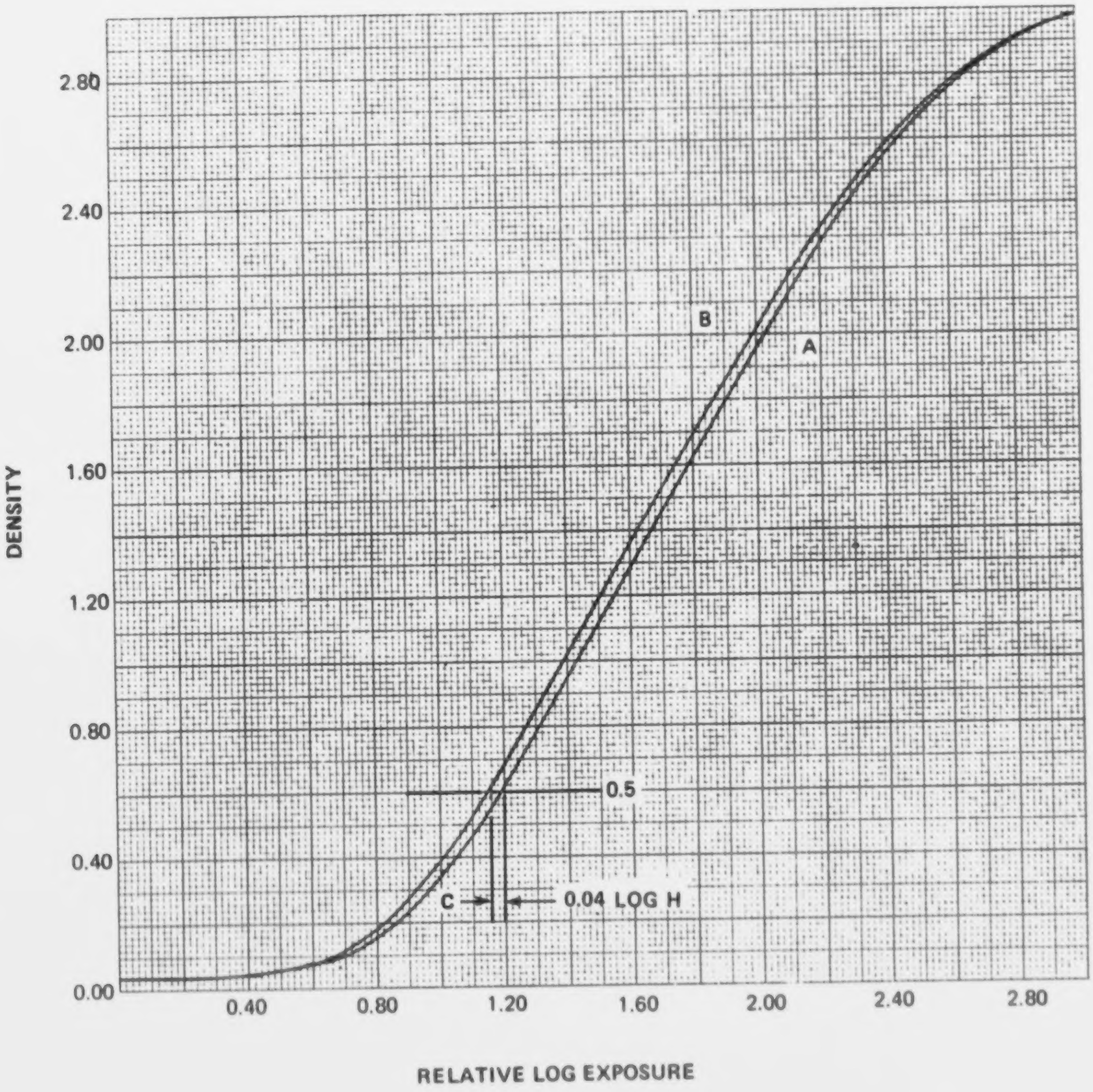
1. How is the general task of correlation employed?

2. What is the minimum size of the film sample?

3. How are the film samples prepared for transport through the processor?

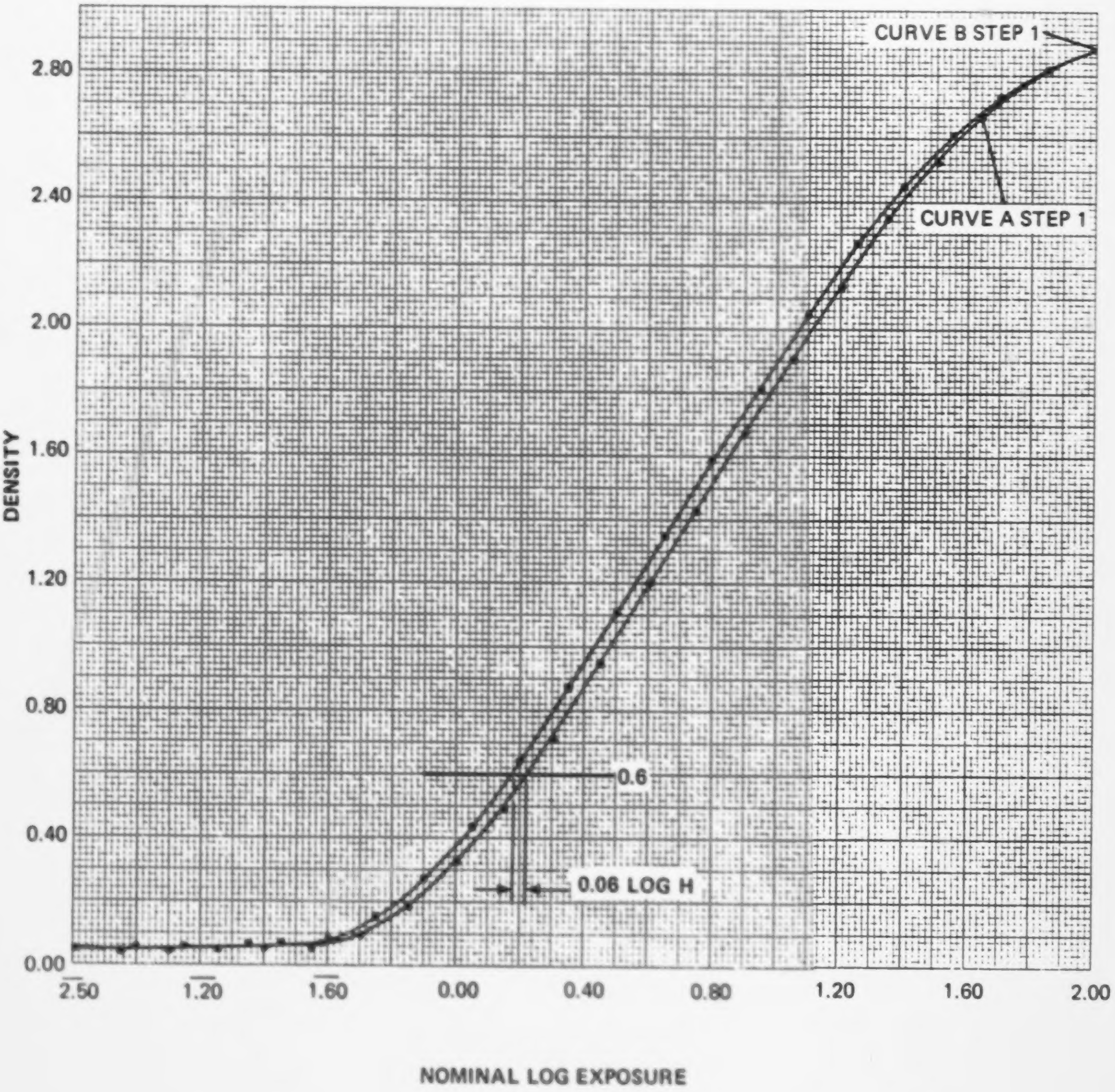
4. How many ways can the nominal exposure be determined?

5. When is the sensitometers said to have good exposure agreement?



A – CORRELATION RESPONSE CURVE, SENSITOMETER NUMBER 1
B – CORRELATION RESPONSE CURVE, SENSITOMETER NUMBER 2
C – ESTIMATE OF THE EXPOSURE DIFFERENCE BETWEEN SENSITOMETER NUMBER 1 AND NUMBER 2

Figure 2-1. A sensitometer correlation test of two sensitometers.



MAXIMUM NOMINAL EXPOSURE OF SENSITOMETER NUMBER 1 = 100 M.C.S.
MAXIMUM NOMINAL EXPOSURE OF SENSITOMETER NUMBER 2 = 63 M.C.S.

THE LATERAL DISPLACEMENT BETWEEN CURVES A AND B, 0.06, IS DUE TO VARIABILITY IN THE TEST PROCEDURE AND ERROR IN THE EXPOSURE CALIBRATION OF ONE OR BOTH OF THE INSTRUMENTS.

Figure 2-2. Correlation test of two sensitometers having different nominal exposures.

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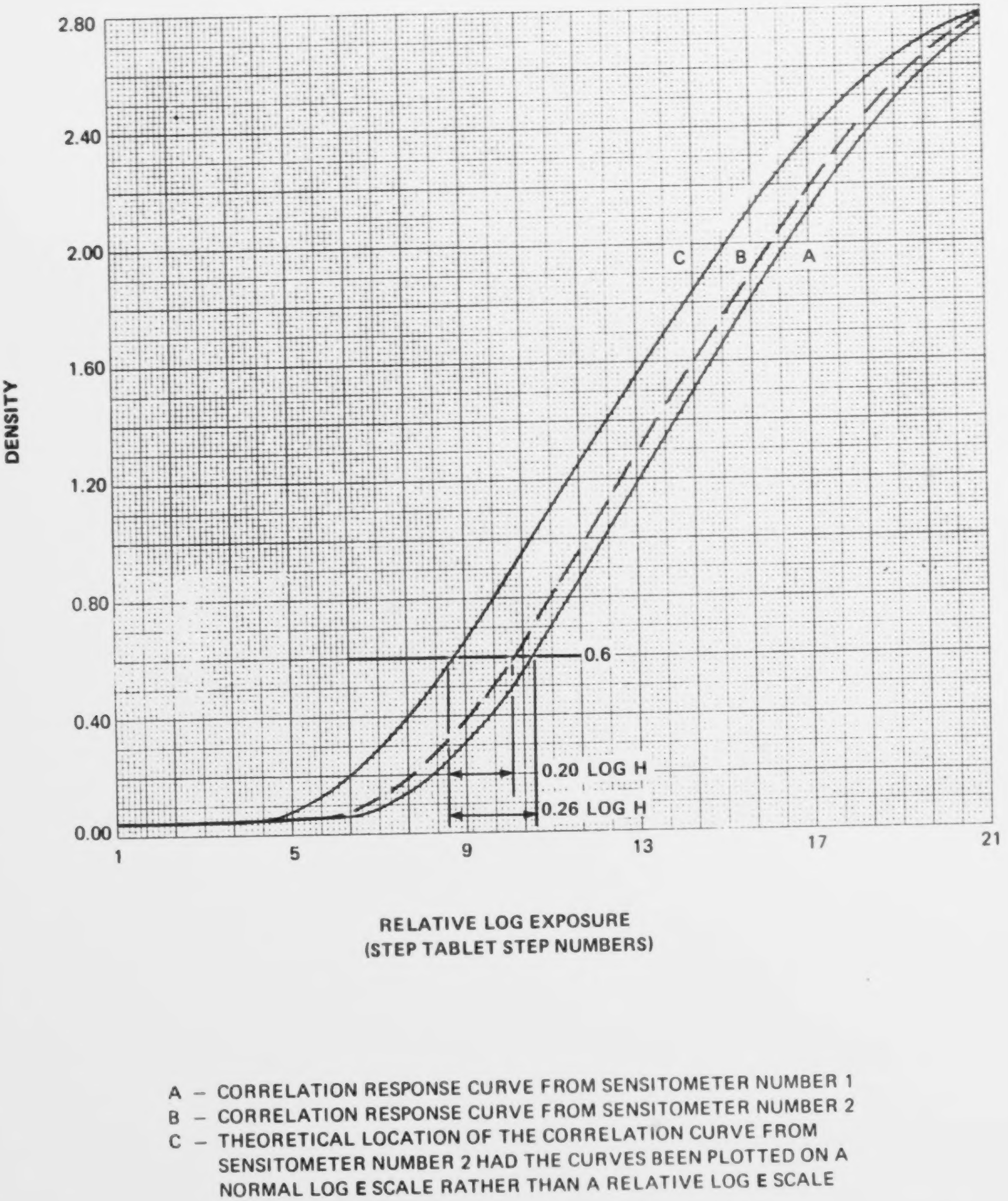


A – CORRELATION RESPONSE CURVE FROM SENSITOMETER NUMBER 1
B – CORRELATION RESPONSE CURVE FROM SENSITOMETER NUMBER 2
C – THEORETICAL LOCATION OF THE CORRELATION CURVE FROM SENSITOMETER NUMBER 2 HAD THE CURVES BEEN PLOTTED ON A NORMAL LOG E SCALE RATHER THAN A RELATIVE LOG E SCALE

Figure 2-3. A correlation test of two sensitometers having different nominal exposure. The response curves are plotted with respect to relative log exposure.

704. State the laboratory certification procedures as they relate to the quality control program.

Laboratory Certification Procedures. Certification of production equipment is a vital phase of the quality control program. Basically, it is a series of comprehensive performance tests that are used to assure that each piece of equipment is in proper working order. Additionally, it provides a "test run" during which the actual performance of the equipment and procedures can be evaluated relative to the end product.

Immediately prior to actual mission operations, all equipment that is used to handle original negative and/or duplicate masters must be physically inspected for proper mechanical and/or electrical functioning, tested in an operational mode, and certified to be free from conditions that would degrade the imagery.

A laboratory certification procedure must be specifically designed to meet the particular requirements of the facility in which it is to be performed. The level of excellence required in the photographic output is the determining factor in the selection of specific equipment for certification and in the design of specific certification procedures and tests.

For an imagery production laboratory, the following equipment must be included: processors, printers, titlers, film cleaners and waxers, viewing devices, and other product-handling and quality-measuring devices. The certification procedures include individual equipment and instrument calibration and correlation between the devices to insure a minimum of variability in the quality of the output products.

For any effective system of quality control, you must consider the performance of the printers and make periodic checks to detect any malfunctions. The basic procedure is based upon making test exposures for comparison with a previously exposed standard. The true measure of printer performance is its capability to recreate (within specific tolerances) the same printing conditions that are used in making the "standard." The certification procedure recommended is based upon concepts of tone control. It is designed to quantitatively evaluate printer performance by precise measurement of selected sensitometric and image quality properties of the duplicated product.

A detailed explanation of the printer certification system is presented in this section. Briefly, a "simulated negative"—in one composed of a calibrated continuous wedge or step tablet, a high contrast resolving power target, and in some instances, typical pictorial imagery, which was previously prepared under certified conditions—is used to establish sets of high, medium, and low contrast "tone control (H & D) curves." These curves graphically display the density response of a particular duplicating material to the "simulated negative" under various conditions of exposure. The densitometric response of the processed duplicate material is then compared to that of the tone control curves and a matching condition selected.

Certification then rests upon an evaluation of the test output material as to how precisely the printer in question has duplicated the printing exposure conditions used to produce the selected tone control curves. Additionally, an evaluation must be made of the image quality of the reproduction to insure that the transfer process has not distorted or degraded the imagery as contained in the original. Factors which must be considered are resolution, physical abrasions and scratches, linear distortion, and slippage and/or adequacy of contact between the negative and raw stock.

Exercises (704):

1. What is a vital phase of the quality control program?

2. What does certification of production equipment entail?

3. What is the determining factor in the selection of specific equipment for certification?

4. List the equipment usually found in an image reproduction laboratory.

705. State how to certify the premission of processors and support equipment and list the steps in the Quality Assurance Test for two types of film evaluations.

Premission Certification. Premission certification of processors must be performed to detect and correct any mechanical and/or sensitometric conditions that could lead to the degradation of the information content of the image being processed. Certification of the processor is absolutely imperative when original negative materials are being processed; the resulting economy of time and materials makes certification highly advisable for use when processing duplicate materials.

The objective of the physical portion of the processor certification task (Quality Assurance Test) is to insure that the processor or the processing system does not cause physical degradation of the film. In brief, this test calls for two types of film evaluations:

(1) Physical defects such as abrasions, scratches, etc., caused by the mechanical portions of the processor.

(2) Processing defects; i.e., water spots, developer sprayback, mottle, chemical stain, etc.

The sensitometric certification consists of processing sensitometric control strips and the use of densitometric measurements to determine if the desired photographic result has been obtained.

Support equipment must be given the same priority of consideration afforded major production equipment and metrology instruments. The actual certification of viewers,

film cleaners, titlers, etc., consists of performance tests and physical inspections conducted prior to a mission to assure that the equipment is in proper working order and will not abuse the film in any way.

Exercises (705):

1. Why is it necessary to perform premission certification of processors?

2. What is the objective of the physical portion of the processor certification task (Quality Assurance Test)?

3. List the steps in the Quality Assurance Test as it relates to the two types of film evaluation.

2-2. Premission Certification of Film Processors

Processing facilities are entrusted with the critical responsibility of processing original negatives in a manner that will minimize the possible loss or distortion of the informational content. Because the facility has only one chance to process this unique and irreplaceable information, it is essential that all possible precautions be taken to insure that the material is handled competently. The premission certification of processors is performed prior to processing any original or duplicate film to detect conditions which will tend to degrade the informational content of the processed imagery.

706. List the tasks for the premission certification of the film processors, and state the instructions that describe mission requirements for the certification of film processors.

Tasks and Instructions for Premission Certification of the Processors. The premission of the processors is concerned with the following tasks:

(1) Processor startup procedures.
(2) Physical quality of the processed material.
(3) Freedom from processing defects.
(4) Uniformity of processing.
(5) Attainment of desired sensitometric characteristics.

Instructions that delineate mission requirements for the certification of film processors are issued by the process control section. These instructions specify the film type and width and the sensitometric specifications. The process aim curve for the desired sensitometric response is consulted to determine the chemical and mechanical requirements. The process aim curve data sheet specifies the chemistry to be used, replenishment rates, temperature, processor speed (transport speed), machine configuration (stranding of film), and any additional pertinent information. Simultaneously, instructions are issued to the chemical mixing and sensitometry sections to prepare the necessary chemistry and process control strips, if sufficient quantities are not on hand.

The processor section then prepares the processors for certification. This task is outlined in the processor startup instructions and includes a visual examination of the transport mechanism; threading the leader material as specified by the process aim curve standards; checking the chemical distribution, recirculation, and filtration system to insure that the proper valves are opened and closed; loading the processor with chemicals; and bringing the processing solutions to temperature, etc.

The actual certification consists of Sensitometric Evaluation and Quality Assurance Tests. The sensitometric evaluation consists of processing sensitometric strips to determine if the desired photographic response (sensitometric curve) is being maintained and also if the process is stable. The quality assurance test consists of three areas of evaluation: physical defects, processing defects, and processing uniformity. The evaluation for physical defects consists of a visual examination of approximately 100 feet of flashed material on both the emulsion and base sides for scratches, abrasions, embedded dirt, dimples, deckled edges, and other physical defects.

Processing defects (water spots, developer sprayback, mottle, chemical stain, etc.) that are attributable to the processing solutions and their application are also evaluated at this time. If defects are noted, the processor crew chief is notified immediately as to the type of defects; their location; whether it is random, repetitive, or continuous; and, if known, an indication of the possible cause and its location. The third area of evaluation, processing uniformity, consists of evaluating the density uniformity across the film width. This provides an indication of the developer and short-stop processing uniformity and is used to detect such problems as these: clogged or misaligned spray nozzles, improper solution pressure at the spray nozzles, etc.

The test imagery for the processor certification test is generally exposed during the previous mission when the printers were certified for use. If a supply of this material is kept on hand, the processor certification will not be delayed as a result of the printer failing to certify. Note that the film must be of the same type and width as used in the mission.

In some instances, it may be necessary to ripen (age) the freshly developed solution to bring it into standard. This is usually the case when a freshly mixed developer solution is used as a replenisher. The ripening can be accomplished artificially by the addition of bromide and iodide (usually in the form of potassium or sodium salts) to increase the restraining effect, and the addition of acetic acid to lower the pH value. Ripening can also be accomplished by processing several hundred feet of either flashed or simulated mission material. Simulated mission material is imagery consisting of an aerial scene which is typical in density values of an average mission roll.

The certification roll of flashed material, simulated mission material, and sensitometric strips are processed as soon as the processor has stabilized at the desired transport speed and temperature. The stabilization may require the processing of several rolls of material, depending upon the size of the processor tank or sump and the change that must take place in the composition of the solutions before the process stabilizes. Leader material is spliced between certification rolls in order for the transport system to be stopped between certification tests.

The processor is certified for mission use when it has passed the sensitometric and quality assurance tests. The certification is valid for approximately 2 hours, only when the processing solutions are continuously recirculated and maintained at the desired temperature. If the processing of mission material does not commence during this period, the certification is void, and the processor must be recertified.

Exercises (706):

1. List the tasks that you are concerned with in the premission certification of processors.

2. What do the instructions that describe mission requirements for the certification of the film processors specify?

707. State the requirements for the preparation of the processor certification roll.

Preparation of the Processor Certification Roll. The processor certification roll is assembled during the time that that processor is being brought into temperature control. The roll is assembled at this time, because the sensitometric strips must be stored at 0° F. until shortly after use.

The remainder of the imagery—the flashed material and the simulated product—may be exposed during a previous mission when the printers were known to be instandard and then stored at normal room conditions (less than 60 percent RH. and less than 75°F.) until they are used. By so doing, the preparation of the processor certification roll is not subject to the delays that would be incurred if the printers were not immediately certified for use.

All of the imagery used in the certification roll must be of the same emulsion type and width as that of the mission material; e.g., 3430 duplicating film 9½ inches wide. This requirement is based upon the fact that different emulsions will exhibit different degrees of susceptibility to physical abrasions and tracking problems. If the mission involves the processing of several widths of the same film type, the certification roll must be of the greatest width. If a processor is certified for the widest film, it is also certified for the narrower widths. The processing of one film width may be changed to a narrower width without stopping the processor by using a segment of leader which is tapered from one film width to another. If during the mission the change is from a narrow to a wide width, it will be necessary to stop the processor and wipe all of the rollers that are not immersed in the solution to remove any particles that may have adhered to the surface after the initial certification test was made. If it is necessary to change the film width being processed to one that is greater than that of the certification roll, a second certification test must first be made at the greater film width.

The design of the certification roll will vary, depending upon the type of processor being used and the previous stability history of the processor. The length of the various portions of the imagery is not critical; therefore, standard roll lengths are used for convenience. A typical certification roll used in certifying a duplicate material processor is as follows:

a. Leader material - 100 ft.
b. Simulated product - 1 roll, 100 ft.
c. Sensitometric strips - 2 strips.
d. Simulated product - 2 rolls, 200 ft.
e. Sensitometric strips - 2 strips.
f. Simulated product - 100 ft.
g. Flash material - 100 ft.
h. Flash material, 180° turn-around splice - 100 ft.
i. Sensitometric strips - 2 strips.
j. Leader material (sufficient length to fill the processor).

If the processor in question has a slow transport rate, it would be desirable to shorten the length of each of the segments to avoid an unreasonably long certification procedure. The example given contains six sensitometric tests which are separated by a simulated product. These six samples will give an indication as to the sensitometric stability of the process. The sensitometric strips may either be spliced into the roll, or they may be secured to the leader material with tape and processed in piggyback fashion. This latter method minimizes the number of splices and allows the strips to be removed easily at the end of the processor. A 90° turn-around splice can be made in the flashed imagery if desired. This would allow a Printing Aperture Illuminance Uniformity Test to be made in order to determine whether or not the detectable density is due to exposure or processing variation.

It is generally a good practice to avoid using large segments of leader material in the interior of the certification roll (between sensitometric strips) because the process chemistry is altered by the replenishment system continuing to function when no material is being developed. This condition tends to increase the concentration of the developing agents while decreasing the bromide concentration. Each replenishment system should be turned off as soon as the last sensitometric strip leaves a particular solution. The purpose of the leader material at the end of the roll is to occupy the processor certification roll being evaluated.

Exercises (707):

1. Why is the processor certification roll assembled during the time the processor is being brought into temperature control?

2. Why must all the imagery used in the certification roll be of the same emulsion type and width as that of the mission material?

3. What does the design of the certification roll depend upon?

4. What is the advantage of securing the sensitometric strips to the leader material tape and processed in piggyback fashion?

5. Why is it generally a good practice to avoid using large segments of leader material in the interior of the certification roll (between sensitometric strips)?

708. State the purpose of the processor startup procedures and the procedure for the processor startup.

Processor Startup Procedures. Processor startup procedures should be prepared by each processing facility to govern the operation of all film processors. The major purpose of the startup procedures is to insure that the processor is operated in accordance with the recommendations set forth by the manufacturers and to outline the tasks which must be performed to bring the processor to an operational state. The procedure includes an inspection of various components to detect conditions that would result in the processor failing to certify under the Quality Assurance (QA) Test. The detection and correction of these faults prior to running the QA test will frequently decrease the time required to certify the processor by eliminating the need for a second QA test. In addition, the inspection procedure may detect parts that are worn, out of adjustment, or operating improperly. Although they may not adversely affect the product quality at that time, they represent a potential equipment failure that could cause a breakdown during the processing of mission material and thereby result in permanent damage to the product and a loss of intelligence information.

Most of the information which should be included in the startup procedure is contained in the respective processor operating and maintenance manuals. These guidelines usually are expanded and modified to meet the specific requirements and operational practices in use at each facility. The startup procedure is also used to assign the responsibility for these tasks to the various processor duty stations.

The content of the startup procedure will vary, depending upon the make and model of the processor and whether or not it is to be used for processing original negatives or duplicates. In addition to stating the initial startup procedure when the machine has been shut down for cleaning and stripped of leader and chemicals, the procedure should cover the daily startup procedure for a machine that has been idle for a short period of time (overnight) or has been on a "standby" status.

Similar procedures should be written for the periodic inspection of the processor during the mission, shutdown maintenance, and cleaning.

Exercises (708):

1. What is the purpose of the processor startup procedure?

2. What does the procedure include for the processor startup?

2-3. Processor Quality Assurance Test

709. State how the Processor Quality Assurance Test is related to the physical quality and processing defect evaluation.

Physical Quality and Processing Defect Evaluation.

The Quality Assurance Test is used to determine if the processor is capable of processing mission material without imparting physical or processing defects that can result in the loss of intelligence information. When a defect is located and identified, every effort should be made to eliminate the cause of the defect. Because different bases, base thickness, and emulsions react differently to various out-of-standard conditions, the Quality Assurance Test should be performed using the same type as used in the mission. Ultrathin base films are more likely to develop tracking problems and exhibit physical defects than the thicker base materials.

Since some defects may be periodic or intermittent rather than continuous, the Quality Assurance Test imagery should consist of at least 50 feet of flashed film, exposed with a certified printer in a manner that will produce a density between 0.60 and 1.00 upon development. In order to distinguish defects which are attributable to the printing operation or any preprocessing handling from those that are imparted during the processing of the material, a 180° turnaround splice is made after the printing operation but before processing. If the defects are imparted during the processing operation, their placement will not be affected by the turnaround splice. Defects which were introduced during the printing operation will appear in a different area in the turnaround portion; i.e., a scratch that is located along the bottom edge of the film will appear along the top edge in the turnaround portion.

The test material should be examined on a light table. Because many defects that are located on the base side of the material are difficult to detect when you are viewing the emulsion side, both sides of the material must be examined. Every effort should be made to identify the defect and determine its cause. By comparing the orientation of the defect on the turnaround portion to that on the remainder of the test film, the problem usually can be attributed to either the printing or processing operations. In some cases the defects may be caused by the turnaround splicing operation. The processor or printing crew should be informed immediately of any problems so that its cause can be located and eliminated as soon as possible.

A processor often produces degradations during the processing of the first hundred feet of film that do not appear in the processing of subsequent film. These short-term, self-eliminating defects frequently occur when a processor is used for the first time after an extended shutdown or after a cleaning or maintenance operation. Some of the typical causes of such problems are abrasions caused by a roller sticking due to crystalized chemicals in the roller bearings; tracking problems resulting in deckled edges, occurring until all of the film that was used to load the processor clears the machine; scratches caused by the chemicals crystalized on the surface of the rollers, etc. To insure that the Quality Assurance Test is not affected by these short-term defects, 100 feet of simulated product should be run before processing the test material. (Reference Procedure 7, Appendix A.)

Exercises (709):

1. What is the Quality Assurance Test used for?

2. Why should the Quality Assurance Test be performed using the same material as that used in the mission?

3. When viewing the test material, why should both sides of the material be examined?

4. What are some of the typical causes for processor defects?

5. To insure that the Quality Assurance Test is not affected by short-term defects, what should you do before processing the test material?

710. State the purpose and procedures of the Processing Uniformity Test.

Processing Uniformity Test. The purpose of the Processing Uniformity Test is to determine whether or not the processing is uniform across the width of the film. Since the test is based on a densitometric evaluation, it primarily serves as an indication of the development uniformity. In addition to detecting processing faults that occur in the developer section of the processor (insufficient or nonuniform agitation, improperly positioned or clogged spray nozzles, temperature gradients, etc.), this test will detect density variations caused by failing to arrest the development. This may be attributable to poor agitation, a nonuniform application of the short-stop bath, an exhausted short stop, a high pH value, etc. This test is not sensitive to minor processing variations that may occur in the short stop, fixing bath, or washing tank. It is possible for a film sample that was inadequately fixed to be certified for this test, even though these defects may severely affect the archival quality of the product, since such defects may have little or no effect on the density of the sample.

The Processing Uniformity Test uses the same imagery as that used for the physical quality and processing defect evaluation. The test consists of an evaluation of the density variations across the width of from one to three film samples. These samples, each about 2 inches wide, may be removed during visual inspection for evaluation by the densitometry section.

This test procedure, the evaluation phase in particular, closely pararallels that of the Printing Aperture Illuminance Uniformity Test. The major difference between them is that of the orientation of the test sample during processing. The Printing Aperture Illuminance Uniformity Test sample is obtained from a 90° turnaround portion, while the Processing Uniformity Test sample is taken from either a normal section or a 180° turnaround section. The easiest method of evaluating this test is through the use of a recording densitometer to obtain a trace of the density variation across the width of the flashed film sample. If a recordings densitometer is not available, a series of readings can be made with a conventional densitometer. These densities are plotted on a sheet of graph paper—density as a function of the distance across the film width. This method is explained in Section Certification of the Printing Aperture Illuminance Uniformity Test.

The range of the minimum and maximum density values is then compared to the test control limits to determine if the processing uniformity achieved is acceptable. The test tolerances are determined by computing the ±3 sigma control limits relative to the variation in the density across the film width of the test samples that were processed when the processor was known to be in control. The ±3 sigma control limits are determined as outlined in the previous section. Tentative control limits can be determined after 10 to 15 tests. As additional data are collected, however, the control limits should be recomputed. To insure that the test yields a valid evaluation, the test samples should not be taken from an area adjacent to a splice, since a splice or any obstruction can affect the degree and the uniformity of the development in the intermediate area.

In order to circumvent the possibility that a question will arise as to whether a density variation is a result of poor processing uniformity or the printing aperture illuminance being uniform, a 90° turnaround splice should be included in each Quality Assurance Test. A Processing Uniformity Test can be performed using a portion of the 90° turnaround splice to determine whether or not the density variation should be attributed to the printing or processing operation. If the results of the Illuminance Uniformity Test certify the performance of the printer, the problem must be attributed to poor processing uniformity.

Exercises (710):

1. What is the purpose of the Processing Uniformity Test?

2. What is the major difference between the test procedure for this test and that of the Printing Aperture Illuminance Uniformity Test?

3. How are both test procedures obtained?

4. How is the test procedure evaluated?

5. What is the purpose of comparing the range of the minimum and maximum density values to the test control limits?

6. To insure whether a density variation is a result of poor processing uniformity or the printing aperture illuminance being uniform, what would you include in the Quality Assurance Test?

711. State the purpose and procedures of the sensitometric certification phase of the Processing Certification Test, and identify what this test insures.

Sensitometric Certification. The sensitometric certification phase of the Processing Certification Test consists of a quantitative comparison between the photographic effect currently produced by the processor and the adopted standards that are embodied in the process aim curve. The completion of this task insures that the desired photographic effect is being produced before the mission material is introduced to the processor. Once the processor is certified and the processing of mission material is started, the process control phase is initiated to evaluate the sensitometric response and to make the necessary adjustments to insure that the processor remains "instandard."

The determination of the current photographic response used in the premission sensitometric certification of the film processor is obtained from the control strips contained in the certification roll. The aim curve and the associated control limits used for the certification are the same as those used for process control during the mission. Establishment of the process aim curves and process control specifications for original negative material was discussed in a previous section.

When certifying a processor that was loaded with fresh, unaged chemicals, the certification roll should contain several sensitometric strips separated by several hundred feet of simulated product. In this manner, the progress of solution aging (seasoning) can be monitored. When aging the developer for an original negative processor, it is a good policy to run one or two additional sensitometric strips with the simulated product, after accepting the first certified sensitometric strip, to assure that the process has stabilized in an "in-control" state. The experience gained in establishing the process aim curves and the replenishment tests will aid in determining the amount of film needed to age the solutions as well as the required frequency of the control strips used during the aging process. The maximum film width possible should be used to expedite matters.

The use of a starter solution or the addition of appropriate amounts of bromide, iodide, and acetic acid to artificially age the solution provides an alternative to processing simulated product and will save considerable time and film. The necessary ingredients to artificially age the solution can be determined by conducting a thorough chemical analysis on sample taken from both initial tank solution and the seasoned developer. A comparison of the results will reveal the quantity and type of ingredient to be added to the initial tank solution.

When recertifying a seasoned process that has been idle for only a short time, the task is considerably easier, since the chemistry should be "in control." In such a case, the certification roll can be kept to a minimum length. Some facilities may find that two adjacent strips are sufficient to evaluate the developer's condition, particularly if it has shown to be reasonably stable in the past. Facilities desiring greater confidence in the sensitometric certification may prefer to process two or more sets of strips, separated by the simulated product of sufficient length to consume 2 to 5 minutes of running time.

It is recommended that evaluations consisting of single sensitometric strips be avoided, since erroneous certifications may result from a nonrepresentative strip or an evaluation error. Instead, a rational subgroup consisting of two or more adjacently processed strips should be used. The results of the two strips should be averaged. This average is then compared to the control limits and plotted on the control chart. The use of rational subgroups decreases the variability or error associated with the evaluation technique.

Exercises (711):

1. What does the sensitometric certification phase of the Processing Certification Test consist of?

2. What does the completion of this test insure?

3. Once the processor is certified and the processing of the mission is started, what phase is initiated to evaluate the sensitometric response?

4. When certifying a processor that was loaded with fresh, unaged chemicals, what should the certification roll contain?

5. When aging developer for an original negative processor, what is the policy for assuring that the processor has stabilized in an "in-control" state?

6. If you wish to save time and film, what alternative procedure can you use to artificially age the solution?

7. Why is it recommended that evaluations consisting of single sensitometric strips be avoided?

8. In exercise 7, what is the recommended procedure?

9. Why are rational subgroups used with the evaluation technique?

712. List the film-handling equipment that replaces many operations previously done by hand, cite the certification procedures of support equipment, and name the test procedures involved.

Support Equipment. Recent advances in technology have resulted in the development of film-handling equipment to replace many operations previously done by hand. Examples of such equipment are viewer's motorized film transports, ultrasonic film cleaners, automatic film titlers, waxers, and film splicers.

Support equipment must be given the same priority of consideration afforded major production equipment and metrology instruments. Improper use, mechanical malfunctions, etc., of this equipment can have a serious impact on the physical condition of the film.

The actual certification procedure is a performance test conducted prior to a mission to assure that equipment is in proper working order and does not abuse the film in any way. The test procedures recommended are:

a. Performance Certification Test (e.g., machine speed, temperature).

b. Physical Abrasion Test (e.g., misalignment of tracking system and burrs on rollers that can tear or mutilate the film).

c. Mechanical Defects Test (e.g., misalignment of tracking system and burrs on rollers that can tear or mutilate the film).

d. Contaminant Inspection (e.g., removal of dust, oil, grease, and other contaminants present on the machines that could be transferred to the film).

Exercises (712):

1. Give examples of film-handling equipment that replace those previously done by hand.

2. Why should support equipment be given the same priority of consideration as that afforded major production equipment and support equipment?

3. What kind of test is the actual certification procedure of the support equipment?

4. Name the test procedures recommended for the support equipment.

713. State the purpose of densitometer certification, what this test includes, and what to do when the difference between the measured and calibrated densities goes beyond the allowable tolerance.

Densitometer Certification of Laboratory Densitometers. The purpose of the densitometer certification is to determine whether or not the instrument's density measurements are within tolerance. The test consists of reading at least three (preferably all 21) of the steps contained on a standard step tablet and then comparing these readings to the step tablet's calibrated densities. If the difference between the measured and calibrated densities is less than the certification tolerance, the instrument is considered "in control." If the difference exceeds the allowable tolerance, the densitometer should be sent to the maintenance section for recalibration.

Certification of laboratory densitometers should be performed daily and the results recorded in a logbook and plotted on the densitometer control chart to provide a permanent record of the densitometer's variability. A separate chart should be prepared for each instrument in order to monitor its performance closely. Although comparing the certification test data directly with the three sigma control limits will indicate when the instrument is out of control, subtle drifts in the instrument's performance will probably go unnoticed if the data is recorded in a logbook only. By monitoring three steps of a step tablet having densities of approximately 0.80, 1.60, and 3.00, an evaluation is made of the linearity of the densitometer's response.

The tolerances are based upon the instrument's previous history of inherent variablility (three sigma control limits), or upon the manufacturer's recommendations (specification limits). The previous history is determined by conducting a statistical evaluation of the densitometer's performance during 3 or 4 weeks of normal operation. If three sigma control limits are used, they should be recalculated periodically as additional data is collected. The tolerance limit of most commercial densitometers is ±0.02.

If a change in the densitometer response results in a significant increase in the variability or decrease in the accuracy, some of the densitometer readings will fall outside of the tolerance limits. This results in the instrument failing to certify and being removed from service. Some of the common problems which cause significant changes in the densitometer's performance are (1) poor power stabilization, (2) faulty vacuum tubes or photocells, (3) changes in the geometry of the optical system, (4) low lamp output, (5) resistors or capacitors changing value, and (6) poor electrical connections. Detailed information on these and other problems is supplied in the manufacturer's maintenance manual.

The degree of confidence required in the densitometer readings determines the frequency and the comprehensiveness of the densitometer certification procedure. Photoprocessing centers should adopt a certification procedure which closely monitors the densitometer's variability. Such a procedure generally involves the reading of every step of a step tablet several times a day. Other facilities which can tolerate a greater degree of densitometer error without significantly affecting their product quality may evaluate only three of the steps (a low, medium, and high density) once per day. A full-step tablet check would then be performed only when one of these three density levels fails to certify.

No one certification procedure is suitable for all levels of densitometer performance. If the test is not sufficiently comprehensive, excessive densitometer variability results. If it is too stringent, needless maintenance costs are incurred and time is lost for lengthy and frequent test. Each laboratory should adopt a procedure that best suits its particular needs.

Exercises (713):

1. What is the purpose of densitometer certification?

2. What does the test for densitometer certification consist of?

3. What do you do when the difference between the measured and calibrated densities exceeds the allowable tolerance?

2-4. Calibration of Temperature Devices

Calibration of the processor is limited to a check of the indicators, flowmeters, and thermostats to insure the accuracy of the readings. The temperature gauges and thermostats are compared to laboratory standards of known accuracy, while the flowmeters and speed indicator require a simple test to determine their accuracy. Adherence to the procedures listed in the following section will enable the processing technician to check the reliability of the processor instruments and make adjustments when necessary.

714. State the purpose of the temperature device certification and the procedure for temperature calibration checks.

Temperature Device Certification. The purpose of the temperature device certification is to determine whether or not the instruments are within tolerance. Most of the processors have two devices that sense the developer temperature. They are the temperature gauge and the thermostat control switch.

Temperature calibration checks are made during normal processor operation, except that the film should not be processed at the time of the check. All systems should be at their operating temperatures for calibration.

Suspend a standard laboratory thermometer of known accuracy which reads in degrees Fahrenheit into one of the developer tanks. Since it is necessary to open the top cover of the processor to place the thermometer in the idle side of the tank, no film processing should be in progress at this time.

Allow sufficient time for the thermometer to reach the developer temperature, and compare the thermometer reading with the thermostat setting.

If necessary, the thermostat setting can be adjusted by loosening the setscrew of the knob and resetting the knob to agree with the thermometer reading obtained in the previous step.

Observe the setting on the developer thermostat and the reading on the temperature gauge. Both readings should be comparable to each other.

If an accurate developer temperature cannot be maintained, first check the incoming water supply to be sure that it is adequate. A minimum pressure of 45 psi on each line is recommended (check manufacturer's specifications), and a constant flow must be maintained.

If the temperature continues to fluctuate, even though the incoming water is maintained at the recommended temperature, the developer circulation system should be checked. If both the incoming water supply and the recirculation are correct, it can be assumed that the thermostat is not operating properly. This may be due to a loose switch mounting screw within the thermostat housing. Remove the thermostat cover and tighten the screws. Also, check to be sure that the plunger operates freely. If the plunger shaft sticks, try to activate it by hand a few times. If this does not correct the situation, replace the thermostat.

Exercises (714):

1. What is the purpose of the temperature device certification?

2. List the two devices that sense the developer temperature.

3. What caliber instrument do you suspend into the developer tanks?

4. What should you check first if an accurate developer temperature cannot be maintained?

5. In exercise 4, if the temperature continues to fluctuate, even though the incoming water is maintained at the recommended temperature, what is the next step?

6. If both the incoming water supply and the recirculation are correct, what can you assume?

715. List the two devices that sense dryer air temperature, and specify the procedure for checking the reliability of the dryer air temperature devices.

Dryer Air Temperature Devices. Two devices sense the dryer air temperature— the dryer air temperature gauge and the dryer air thermostat control switch. Check the reliability of these devices as follows:

a. Place a thermometer into the dryer section at a convenient location to sample the incoming air to the dryer.

b. Allow sufficient time for the thermometer to reach the air temperature and compare the thermometer reading with those obtained in step *a* above.

c. If the thermometer reading does not compare with the reading taken in step *b* above, the dryer thermometer will have to be adjusted.

d. Check the setting of the dryer thermostat against the thermometer. If necessary, reset the position of the thermostat by adjusting the screw in the shaft end behind the calibrated knob. A defective thermostat is indicated by erratic readings on the thermometer, in which case the thermostat should be replaced.

Exercises (715):

1. List the two devices that sense the dryer air temperature.

2. What is placed into the dryer section to sample the incoming air to the dryer?

3. What happens when the dryer air temperature gauge does not coincide with the standard thermometer?

4. What is the dryer thermostat compared against?

5. What conditions would indicate a defective thermostat?

716. State the procedure for checking the accuracy of the water temperature gauge.

Water Temperature Gauge. The water temperature gauge is located on the mixing valve. This gauge can be checked for accuracy as follows:

a. Remove the gauge from the mixing valve by loosening the retaining nut and sliding the unit up and out.

b. Place the gauge together with a standard thermometer into a container of water heated to approximately 100°F.

c. Allow sufficient time for the devices to reach the temperature of the water and compare the readings. The readings should be comparable within 1°.

d. If the gauge reading is incorrect, the gauge pointer must be reset. If resetting is not possible, the gauge must be replaced.

Exercises (716):

1. Where is the water temperature gauge located?

2. How do you remove the gauge from the mixing valve?

3. What do you check the water temperature gauge against?

2-5. Calibration of Speed Indicator

This section is devoted exclusively to discussion of the procedure used in the calibration of the speed indicator and where this is done.

717. State the procedure for calibrating the speed indicator on the Versamat 11-cm processor.

The calibration of the speed indicator should be checked daily. Turn off the processor and proceed as follows:

a. Remove a crossover and place a mark on one of the top 1-inch rack rollers.

b. Turn on the processor and allow it to operate for several minutes; then set the speed control to an indicated reading of 10 feet per minute.

c. Time 40 revolutions of the marked roller with a stopwatch or sweep second hand on a wristwatch. If the processor speed is a true 10 feet per minute, 40 revolutions will require 63 seconds.

d. If 40 revolutions require less than 63 seconds, the true speed is more than 10 feet per minute; if more than 63 seconds is required, the true speed is less than 10 feet per minute. Refer to the speed calibration chart, figure 2-4.

e. With the processor running, adjust the indicator calibration screw on the rear of the indicator to obtain a reading on the speed indicator matching the exact speed shown on the speed calibration chart.

f. Now rotate the speed control knob to show a reading of 10 feet per minute on the speed indicator.

g. Repeat steps *c* through *g* as often as necessary to obtain a true speed of 10 feet per minute when the speed indicator reads 10 feet per minute. The speed indicating system is now calibrated to the true processor drive speed.

Exercises (717):

1. How often should you check the speed indicator?

2. With what do you time the revolutions of the marked rack roller?

3. With what should you match the reading on the speed indicator?

2-6. Flowmeter Calibration

The most widely used type of meter is a glass tube with a tapered bore and a heavy bob. The solution is pumped through the bottom of the tube and moves the bob up. The tube is calibrated directly in milliliters, liters, gallons per minute or percent of total flow, and the like, for water. For other solutions the flow rates may be different, however.

718. Using figure 2-5 as necessary, specify the procedure for flowmeter calibration on the Versamat 11-cm processor.

To provide the accurate control of the solution replenishment rates, the amount of solution passing through the flowmeters must be measured and a calibration curve

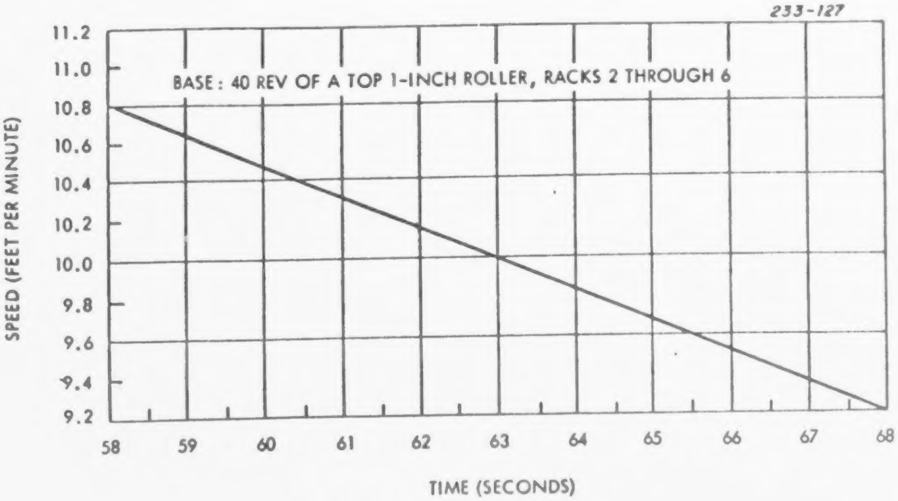


Figure 2-4. Speed calibration curve.

plotted on a graph, as shown in figure 2-5. Proceed as follows to obtain the readings.

a. Disconnect the developer feedline to the processing tank. Check the flowmeter tubes one at a time. When checking the developer flowmeter, make certain that the settings are applied to the developer flowmeter tube.

b. Operate the replenisher pump and collect the solution discharging from the feedline in a graduated cylinder. The flowmeter should be set at 100 ml/min and solution collection must be carefully timed for 1 minute, using a stopwatch or a wristwatch with a sweep second hand so that an accurate "actual delivery" reading will be obtained.

c. Repeat step *b* with the flowmeter settings of 200, 300, 400, and 500 ml/min, respectively, carefully recording the actual delivery for each setting.

d. Repeat steps *a* through *c* for fixer replenisher flowmeter tube.

e. Plot the readings obtained on a graph, as shown in figure 2-5.

f. If the replenishment rates obtained are not comparable with the manufacturer's data for the specific type of solution, the tubes may require cleaning.

g. After cleaning, rerun the test described in steps *a* through *e* above, and compare the result with the chart in figure 2-5.

Exercises (718):

1. How do you provide for the accurate control of the solution replenishment rates?

2. When you disconnect the developer feedline to the processing tank, how do you collect the solution discharging from the feedline?

3. What instrument do you use to time the accurate delivery of the replenishment solution?

4. If the replenishment rates obtained are not comparable with the manufacturer's data, what should you do?

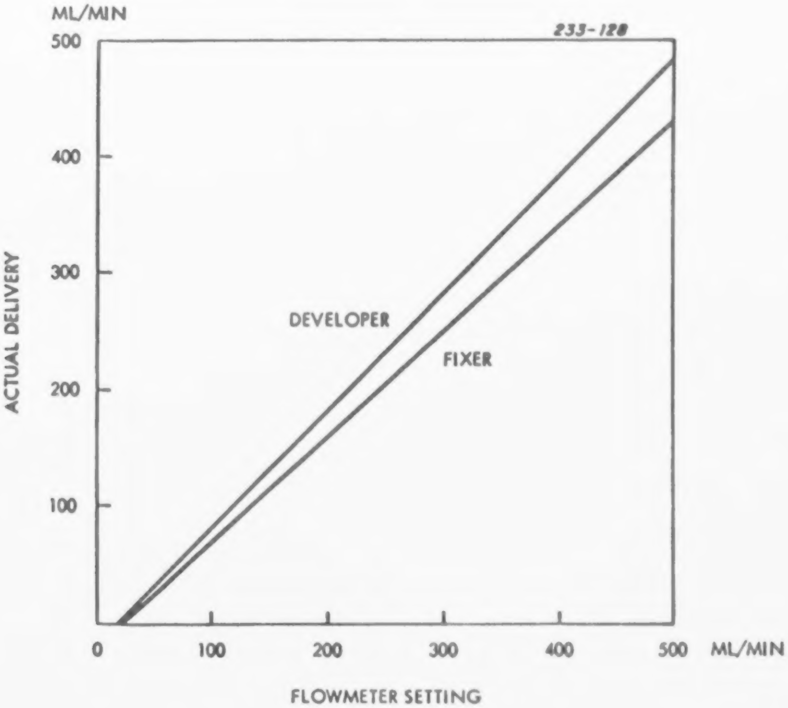


Figure 2-5. Typical flowmeter calibration curves.

2-7. Calibration of Mix Tanks

It is frequently necessary to determine accurately the volume of a mix tank or a recirculation system. This is done either by a titration method or by a spectrophotometric method. The procedure is repeated for each volume or calibration mark being determined. It is only necessary to add the extra amount of solution and water between one volume and the next.

719. State the procedure for determining accurately the volume of a mix tank.

Procedure for Determining Mix Tank Volume. The titration method involves weighing two portions of sodium chloride, dissolving the larger in the tank to be calibrated and the smaller in a volumetric flask. Samples are taken from both solutions and are titrated with silver nitrate, using potassium chromate as an indicator. The true volume of the tank is calculated from the ration of the two volumes of silver nitrate.

Sodium chloride is used in the titration method because of its high uniformity of particle size and low cost. It is inert to carbon dioxide and oxygen and does not form hydrates. The small amount of sodium chloride used to prepare the reference solution must truly represent the large amount used to prepare the tank solution.

In the spectrophotometric method, accurately weighed amounts of metanil yellow are dissolved in the mix tank and in a volumetric flask. The absorbance of each solution is measured on a spectrophotometer, and the true volume of the tank is calculated from the ratio of the absorbances. This method has advantages, in that the amount of chemical required is smaller, and also an analytical balance may be used to measure both portions of the reagent, avoiding the use of less precise balances. What follows very briefly outlines the titration method:

The Titration Method.

- Reagents:
- Sodium chloride, NaCl.
- Potassium chromate, K_2CrO_4, indicator.
- 0.05 N silver nitrate, $AgNO_3$.

a. Preparation of the tank solution of sodium chloride includes these steps:

(1) Add water to the mix tank to bring the level nearly to the calibration mark. Stir thoroughly and withdraw approximately 3 liters for use in making a reference solution.

(2) Weigh accurately sodium chloride to give a concentration of about 0.5 grams per liter in mix tank (e.g., 500.0 grams for a 1000-liter calibration mark). Use the appropriate balance and weigh to the number of decimal places indicated:

- Analytical Balance—for weights between 0.5000 and 49.500 grams.
- Torsion Balance—for weights between 50.00 and 100.00 grams.
- Torsion Balance—for weights between 100.50 and 499.50 grams.
- Triple Beam Balance—for weights between 500.0 and 2500 grams.

(3) Add the sodium chloride slowly in a fine stream to the mix tank, stir for a few minutes, and dilute to the calibration mark. Stir for approximately one-half hour.

b. Preparation of the reference solution of sodium chloride includes these steps:

(1) Weigh on an analytical balance 1.0000 gram from the same batch of sodium chloride used in the mix tank.

(2) Transfer the sodium chloride to a 2-liter volumetric flask, dissolve it in approximately 1600 ml of the water taken from the mix tank and dilute to volume.

c. Titration of two samples of the reference solution is as follows:

(1) Pipet (wipe the pipet before leveling 200.0 ml of the reference solution into a 500-ml glass-stoppered Erlenmeyer flask).

(2) Add 3 drops of potassium chromate indicator.

(3) Titrate with 0.05 silver nitrate from a 50-ml buret, with constant swirling, until the precipitate has a slight orange tint.

(4) Stopper the flask and shake vigorously for approximately 30 seconds.

(5) Add more silver nitrate drop by drop, with swirling, until the first permanent orange tint.

(6) Titrate another 200.0 ml sample of the reference solution by repeating steps (1) through (5) and average the two volumes of silver nitrate used.

d. Titration of two samples of the mix tank solution is as follows:

(1) Withdraw a sample of the mix tank solution. Pipet (wipe the pipet before leveling) 200.0 ml into a 500-ml glass-stoppered Erlenmeyer flask and repeat steps (2) through (5), under "Titration of two samples of the reference solution."

(2) Withdraw another sample from the mix tank and titrate a 200.0-ml portion as before.

Calculations:

$$\left[\frac{(2.0)(\text{ml AgNO}_3\text{ for ref soln})}{(\text{ml AgNO}_3\text{ for mix tank solution})}\right] + \left[\begin{matrix}\text{g NaCL added}\\ \text{to mix tank}\end{matrix}\right] = \begin{matrix}\text{volume of}\\ \text{mix tank in}\\ \text{liters}\end{matrix}$$

The following segment outlines the spectrophotometric method.

a. Special apparatus: Beckman Model DU Spectrophotometer 1-cm No. 2300–10–73.

b. Reagents: Metanil yellow.

c. Preparation of the tank solution of metanil yellow includes these steps:

(1) Add water to the mix tank to bring the level nearly to the calibration mark. Stir thoroughly and withdraw approximately 5 liters for use in making the reference solution and for use as a blank in the spectrophotometer measurements. (It is necessary that the same water at the same temperature be used for both solutions.)

(2) Weigh to 4 decimal places on an analytical balance enough metanil yellow (previously powdered if necessary) to give a concentration of about 0.01 gram per liter in the

mix tank (e.g. 10.0232 grams for 1000-liter calibration mark).

(3) Add approximately 1 liter of water to the metanil yellow contained in a beaker, stir, and decant into the mix tank. Use care to keep any solid dye in the beaker. Repeat with 1-liter portions until all of the metanil yellow is dissolved and add to the mix tank.

(4) Dilute the solution to the calibration mark and stir for approximately one-half hour.

d. Preparation of the reference solution of metanil yellow includes these steps:

(1) Weigh on an analytical balance 0.4000 gram from the same batch of metanil yellow used in the mix tank.

(2) Transfer the metanil yellow to a 2-liter volumetric flask, dissolve it in part of the water taken from the mix tank and dilute to volume.

(3) Pipet (wipe the pipet before leveling) 50.0 ml of this solution into a 1-liter volumetric flask and dilute to volume with water from the mix tank.

e. Measurement of the absorbance of the solutions against an air blank has these steps:

(1) Measure the absorbance of the diluted reference solution at 425, 430, 440, 445, and 450 nm. Use the tungsten lamp. See instructions for operation of the spectrophotometer.

(2) Withdraw a sample of the mix tank solution and measure its absorbance at each of the wavelengths listed in step (1).

(3) Withdraw another sample from the mix tank and repeat the measurements.

(4) Average the two measurements at each wavelength for the mix tank solution.

f. Measurement of the absorbance of the water from the mix tank involves these steps:

(1) Measure the absorbance of the water (refer to section *c*, "Preparation of tank solution of metanil yellow" and each of the wavelengths listed in section *e*, step (1), "Measurement of the absorbance of the solutions against an air blank.")

$$\left[\frac{(100)(A_{425}\text{ of ref soln} - A_{425}\text{ of water})}{A_{425}\text{ of tank soln} - A_{425}\text{ of water}}\right] \times \left[\begin{array}{c}\text{grams of metanil}\\ \text{yellow added to}\\ \text{tank}\end{array}\right] = \begin{array}{c}\text{volume}\\ \text{of mix}\\ \text{tank in}\\ \text{liters}\end{array}$$

(2) Repeat the calculation using the absorbances of the solutions at each of the other wavelengths.

(3) Average the six volumes obtained and report the average value. The range of the six values is an indication of the precision of the work.

Exercises (719):

1. List the two methods used to determine accurately the volume of a mix tank.

2. What does the titration method involve?

3. In exercise 2, the samples taken from both solutions are titrated with what titrant?

4. In exercise 3, what is used as an indicator?

5. What salt do you use to prepare the reference solution?

6. In the spectrophotometric method, what dye do you use for the reference solution?

7. What in the reference solution is measured on the spectrophotometer?

CHAPTER 3

Test and Evaluate

IN VOLUME 3 of the CDC, we discussed the use of Phenidone as a developing agent. We gave you some of the concepts involved in developing a new kind of processing solution. Once again, let us use Phenidone as a developing agent, but this time we will combine it with Glycin, and evaluate the solution. The evaluation is somewhat different for each set of specified conditions. Our discussion is restricted to certain parameters only and does not set a specific pattern of evaluation for any and all solution evaluations. You will note that this evaluation is based largely upon comparison of the new developer to a known developer. Additionally, this new formula was formulated from a known developer—specifically AF Developer No. 4. Thus, some prediction can be made before the new solution is prepared.

720. State how the formulation of a low-contrast developer is used with aerial rollfilm at 90°F in continuous processing equipment.

Selection of the Solution. The principal objective of this Air Force study was the formulation of a low-contrast photographic developer for use with aerial rollfilm at 90°F in continuous processing equipment. The film studied, Kodak Plus X Aerecon, is specifically designed to have high maximum gamma to counteract the reduction in contrast caused by atmospheric haze. There are circumstances where variations in haze or in the altitude from which scenes were photographed make it desirable to develop this film to a low contrast. At present, D-76 modified by the addition of borax can be used at 68°F to produce low-contrast development. However, at elevated temperature (90°F), this developer has poor stability and does not give satisfactory development.

In general, photographic emulsions are formulated to satisfy a specific set of requirements. Certain properties of the finished emulsions are interrelated, and treatments that affect one of these properties often affect the other correspondingly. Speed and gamma are two such properties. Thus, if an emulsion is compounded to give a certain speed and a high gamma under the recommended processing conditions, it is difficult to produce low-contrast development with no loss in speed by variations in processing.

With a developer formulation containing 1-phenyl-3-pyrazolidone (Phenidone) and N-(p-hydroxyl-phenyl)-glycin (Glycin) as the active agents, a reasonable compromise between gamma and speed was reached. This formulation can be used for low-contrast development of the aerial film at 90°F. It satisfies the criterion of availability of developing agents. Glycin is offered by at least one major chemical producer and several suppliers of laboratory chemicals, and sources of Phenidone are already available to the Air Force. A comparison between preselected performance characteristics and those obtained with the Phenidone-Glycin developer is given in the following table:

Performance Factors	*Desired*	*Attained*
Processing Time	<2 min	90 sec
Exposure Index	80	70
Gamma	1.00-1.30	1.20-1.50
Maximum Density	>3.00	>3.00
Chemical Fog	<0.15	<0.15

The Phenidone-Glycin developer was prepared according to the following formulation:

Sodium Sulfite	50.0g
Sodium carbonate (monohydrate)	80.0g
Potassium bromide	2.0g
Benzotriazole	0.2g
Glycin	20.0g
Phenidone	1.0g
Water to make 2 liters	

The dry ingredients were added, in the order listed, to 1800 ml of warm (90°F) water, and the resulting solution was made up to 2 liters. The pH of this solution was 10.2. If the Glycin portion of this formulation is replaced by a molar equivalent of hydroquinone and the Phenidone concentration is halved, the formulation is identical with Armed Forces Developer No. 4. Our combination of ingredients is a good starting point, since the desired end product was a developer suitable for packaging as a single blended dry powder. (Armed Forces Developer No. 4 is packaged as a single blended dry powder, and suitable stabilizers are available for such a blend.)

Exercises (720):

1. List the two interrelated properties of a processed emulsion.

2. Why was Kodak Plus X Aerecon film used in this study?

3. What criterion does a developer containing Phenidone and Glycin satisfy?

4. Why can't D–76 modified by the addition of borax be used at 90°F?

5. What are the advantages of using a Phenidone–Glycin developer for Plus X Aerecon film?

721. Using figures 3-1 to 3-11, state how Phenidone–Glycin developer reacts under various processing conditions.

Evaluation Against Conditions of Use. The behavior of the Phenidone–Glycin developer under various processing conditions is illustrated in the series H and D curves comprising figures 3-1 through 3-11. Curves for various processing times at 90°F are shown in figures 3-1 and 3-2 (films of different emulsion number). A 90-second developing time appears to give the optimum balance of speed and gamma. Increased developing time produces a large increase in gamma with a negligible change in speed. The Phenidone–Glycin developer is also suitable for use at 68°F, producing the developer shown in figure 3-3. Under these conditions, higher gammas are obtained, and the developer cannot be regarded as a low-contrast developer. However, according to data published by Kodak (Publication No. M4, Kodak Materials for Aerial Photography), a low-contrast developer is available for use with Plus X Aerecon film at 68°F.

Although the use of Phenidone–Glycin developer is not expected to affect the filter factors for Plus X Aerecon film, these factors are checked. The results are shown in figure 3-4. The filter factors are within the specifications limits for this type of film and compare favorably with filter factors determined with D–19 as the developer.

It was desired that the developer be capable of processing 5000 square inches of film per gallon of solution with less than 30 percent loss in film speed, less than 15 percent loss in gamma, and less than 0.20 chemical fog. For the actual test, 3000 square inches of film were processed in a 2-liter portion of developer. Curves obtained at the beginning and end of the test are shown in figure 3-5. To simulate conditions of an exposed roll or film, all of the film processed in this test was given a sensitometric exposure.

In addition to the previous performance characteristics, it was desirable to store the developer ingredients, packaged as a dry powder, at 120°F for 7 days without harmful effects. The packaged Phenidone–Glycin developer showed slight caking after storage, but the powder was readily soluble in water. The solution prepared from the stored developer produced the development shown in figure 3-6. The gamma for the stored material is somewhat higher than for the control. The only apparent difference between the solution from the freshly prepared powder and that from the stored powder was an almost insignificant increase in pH (about 0.05 units), possibly caused by some liberation of carbon dioxide during the period of storage at elevated temperature.

Another desirable feature was the storage of the developer solution in a stoppered container at a temperature that does not exceed 100°F for 1 month without deterioration. Since the test conditions were not strictly defined for the temperature tests, the developer solution (contained in a glass bottle with a tight screwcap) was stored in an oven set at 95°F, but showing a temperature variation of ±5°F. In this way an average temperature close to 100°F was fulfilled. At the end of 1 month, a sensitometric comparison was made between this solution and a freshly prepared solution of the Phenidone–Glycin developer. Identically exposed strips of Plus X Aerecon film were processed for 90 seconds at 90°F in each developer. The results of these tests are shown in figure 3-7. Some deterioration of the stored solution is evident, but the fall-off in properties of the developed film is not serious. The gamma is in the desired range, and the speed is practically unchanged. The maximum density was the most seriously affected property.

Exercises (721):

1. What is the best developing time for the optimum balance of speed and gamma illustrated by the curves for various processing times in figures 3-1 and 3-2 (films of different emulsion in number)?

2. What assumptions can you draw from figure 3-3, Phenidone–Glycin at 68°F?

3. In exercise 2, can the developer be considered as a low-contrast developer?

4. Curves obtained at the beginning and end of the test as shown in figure 3-5 show what percentage loss in film speed and gamma?

DATE ____

U P NUMBER ____

PREPARED BY LH

TYPE IB

CLASS A

MANUFACTURER Kodak

EXPIRATION DATE 10-60

EMULSION NUMBER 8401-58-11

LAMP 5500°K

EXPOSURE TIME 1/25 sec

WEDGE NUMBER ____

DEVELOPER ____

TIME ____

TEMPERATURE ____ °F

TOTAL DENSITIES

F ____
1 ____
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____
8 ____
9 ____
10 ____
11 ____
12 ____
13 ____
14 ____
15 ____
16 ____
17 ____
18 ____
19 ____
20 ____
21 ____

BASE DENSITY ____

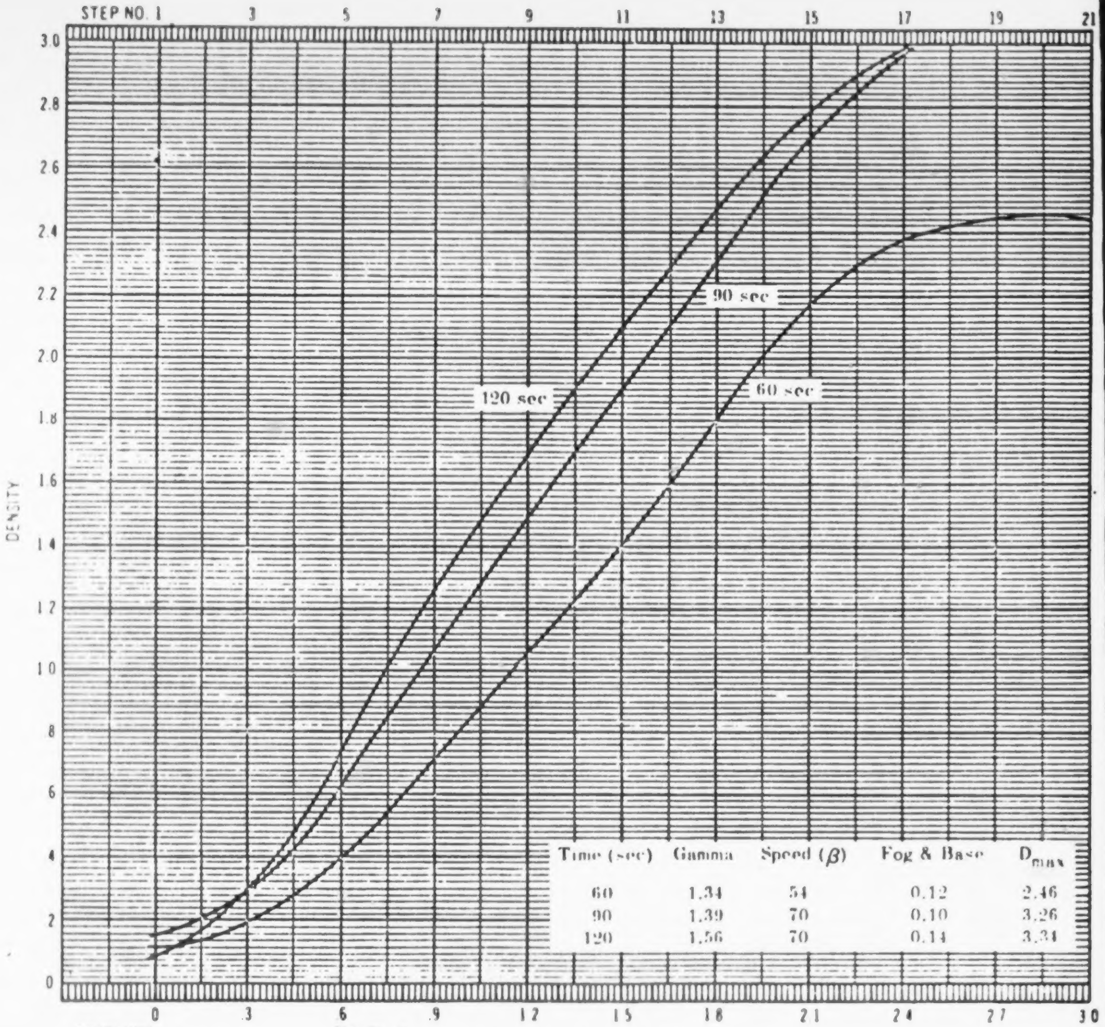
SENSITOMETRIC PROPERTIES

SPEED ____

GAMMA ____

FILTER ____

FILTER FACTOR ____



Time (sec)	Gamma	Speed (β)	Fog & Base	D_{max}
60	1.34	54	0.12	2.46
90	1.39	70	0.10	3.26
120	1.56	70	0.14	3.34

ABSOLUTE LOG E 7.52-10

Figure 3-1. Phenidone-Glycin at 90° F.

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DATE 7-10-61
U P NUMBER
PREPARED BY P.W.

TYPE IB
CLASS A
MANUFACTURER
EXPIRATION DATE
EMULSION NUMBER 6401-33-1

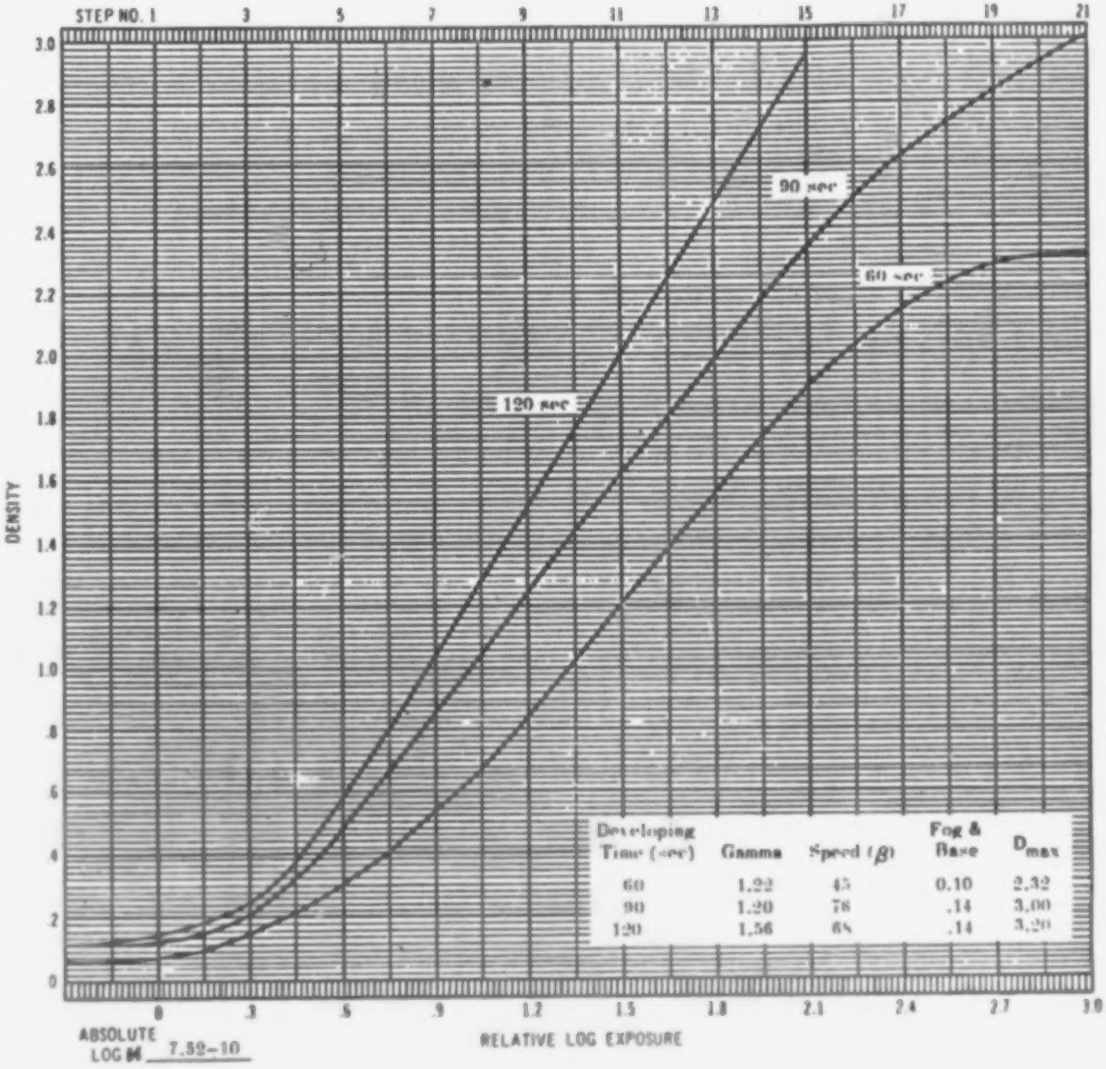
LAMP
EXPOSURE TIME 1/25 sec
WEDGE NUMBER
DEVELOPER
TIME 90 sec
TEMPERATURE 90 °F

TOTAL DENSITIES

F ____ 11 ____
1 ____ 12 ____
2 ____ 13 ____
3 ____ 14 ____
4 ____ 15 ____
5 ____ 16 ____
6 ____ 17 ____
7 ____ 18 ____
8 ____ 19 ____
9 ____ 20 ____
10 ____ 21 ____
BASE DENSITY

SENSITOMETRIC PROPERTIES

SPEED
GAMMA
FILTER
FILTER FACTOR



ABSOLUTE LOG E 7.32-10

Developing Time (sec)	Gamma	Speed (β)	Fog & Base	D_{max}
60	1.22	45	0.10	2.32
90	1.20	78	.14	3.00
120	1.56	68	.14	3.20

Figure 3-2. Phenidone-Glycin at 90° F. (emulsion change).

DATE 7-7-61
U P NUMBER
PREPARED BY P.W.

TYPE IB
CLASS A
MANUFACTURER Kodak
EXPIRATION DATE
EMULSION NUMBER 8401-33-1

LAMP 5500° K
EXPOSURE TIME 1/25 sec
WEDGE NUMBER
DEVELOPER Glycin-Phenidone
TIME
TEMPERATURE 68 °F

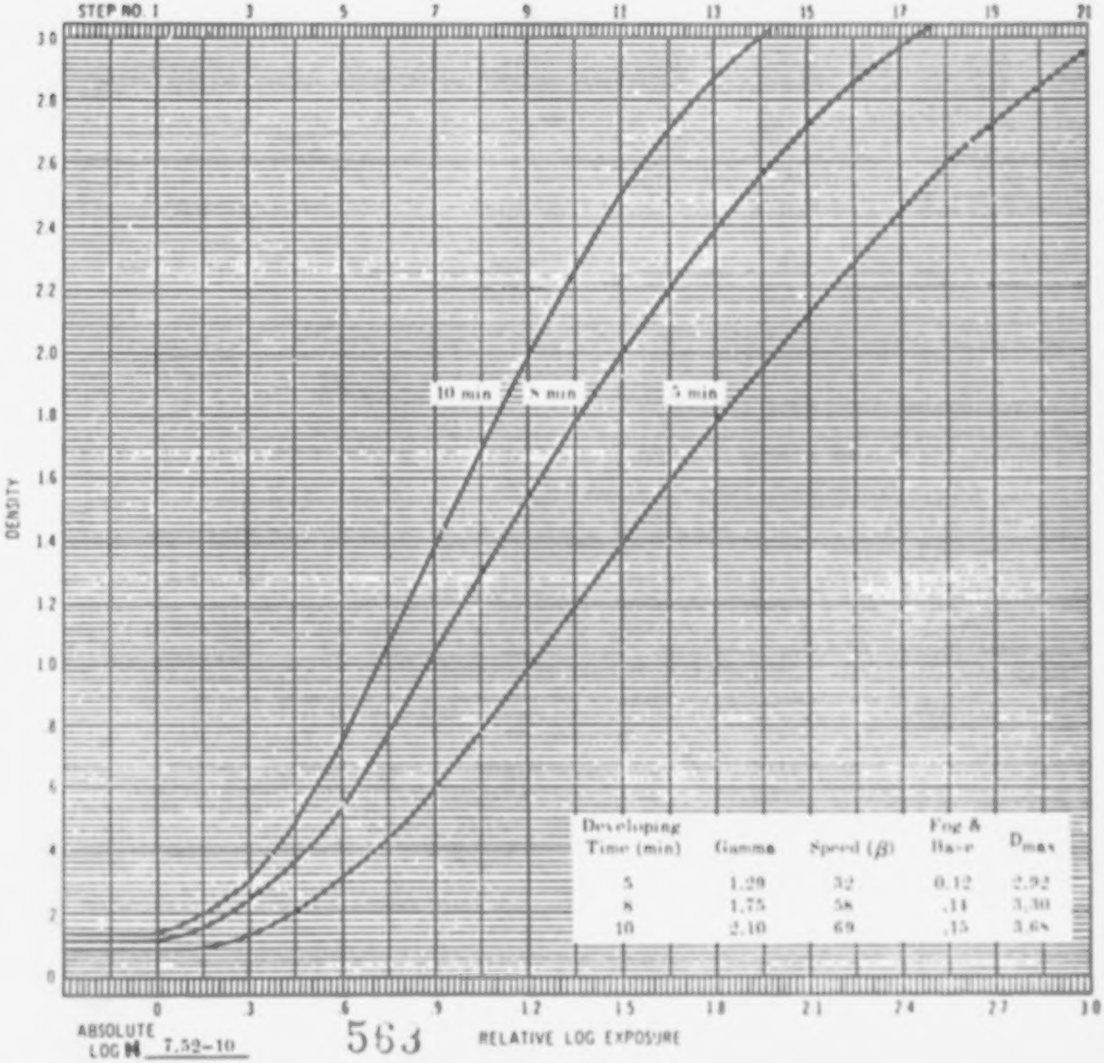
TOTAL DENSITIES

F		11	
1		12	
2		13	
3		14	
4		15	
5		16	
6		17	
7		18	
8		19	
9		20	
10		21	

BASE DENSITY

SENSITOMETRIC PROPERTIES

SPEED
GAMMA
FILTER
FILTER FACTOR



Developing Time (min)	Gamma	Speed (β)	Fog & Base	D_{max}
5	1.29	32	0.12	2.92
8	1.75	58	.14	3.30
10	2.10	69	.15	3.68

ABSOLUTE LOG H 7.52-10

Figure 3-3. Phenidone-Glycin at 68°F.

DATE 7-5-61

U P NUMBER

PREPARED BY P.W.

TYPE 1B

CLASS A

MANUFACTURER Kodak

EXPIRATION DATE

EMULSION NUMBER 8401-33-1

LAMP

EXPOSURE TIME 1/25 sec

WEDGE NUMBER

DEVELOPER Phenidone-Glycin

TIME 10 min

TEMPERATURE 68 °F

TOTAL DENSITIES

F
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

BASE DENSITY

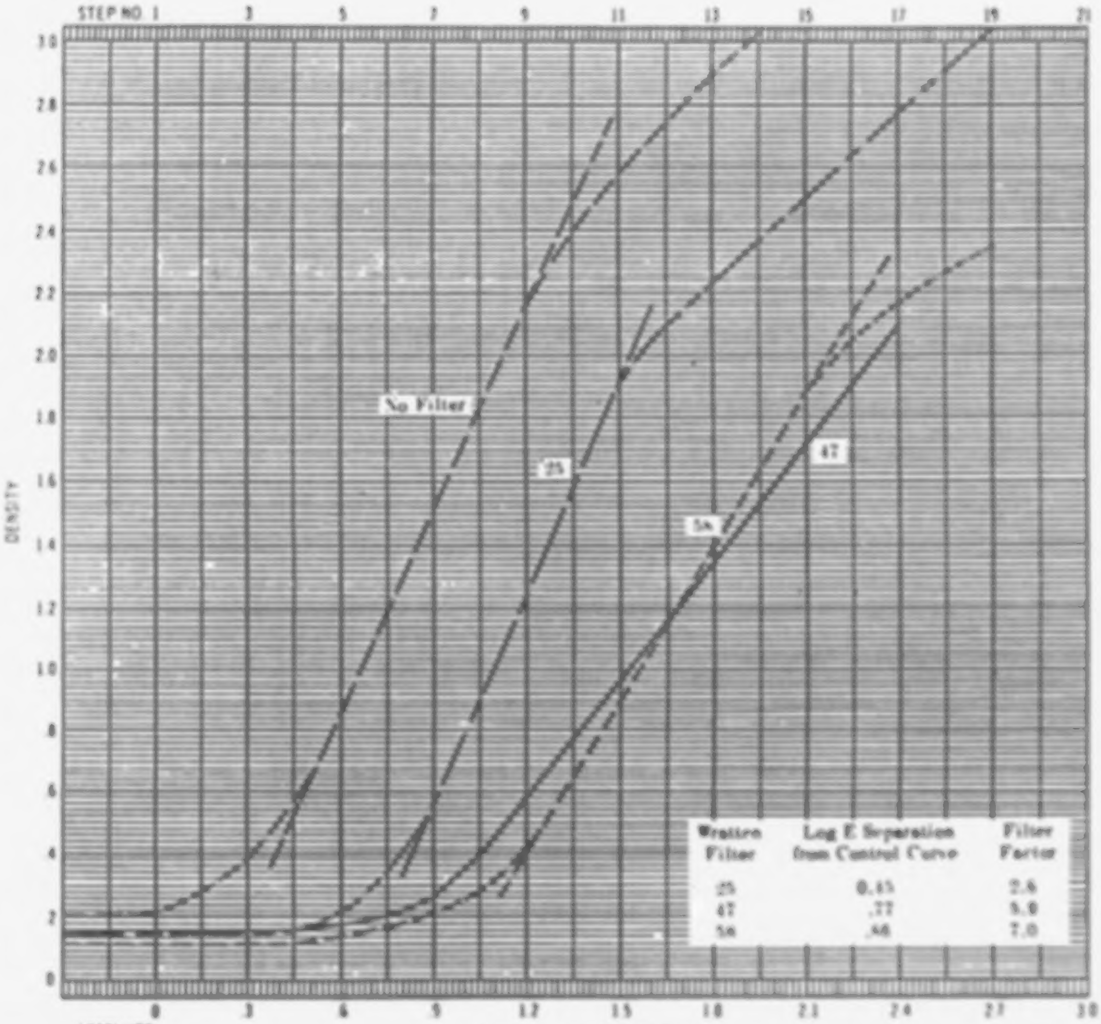
SENSITOMETRIC PROPERTIES

SPEED

GAMMA

FILTER

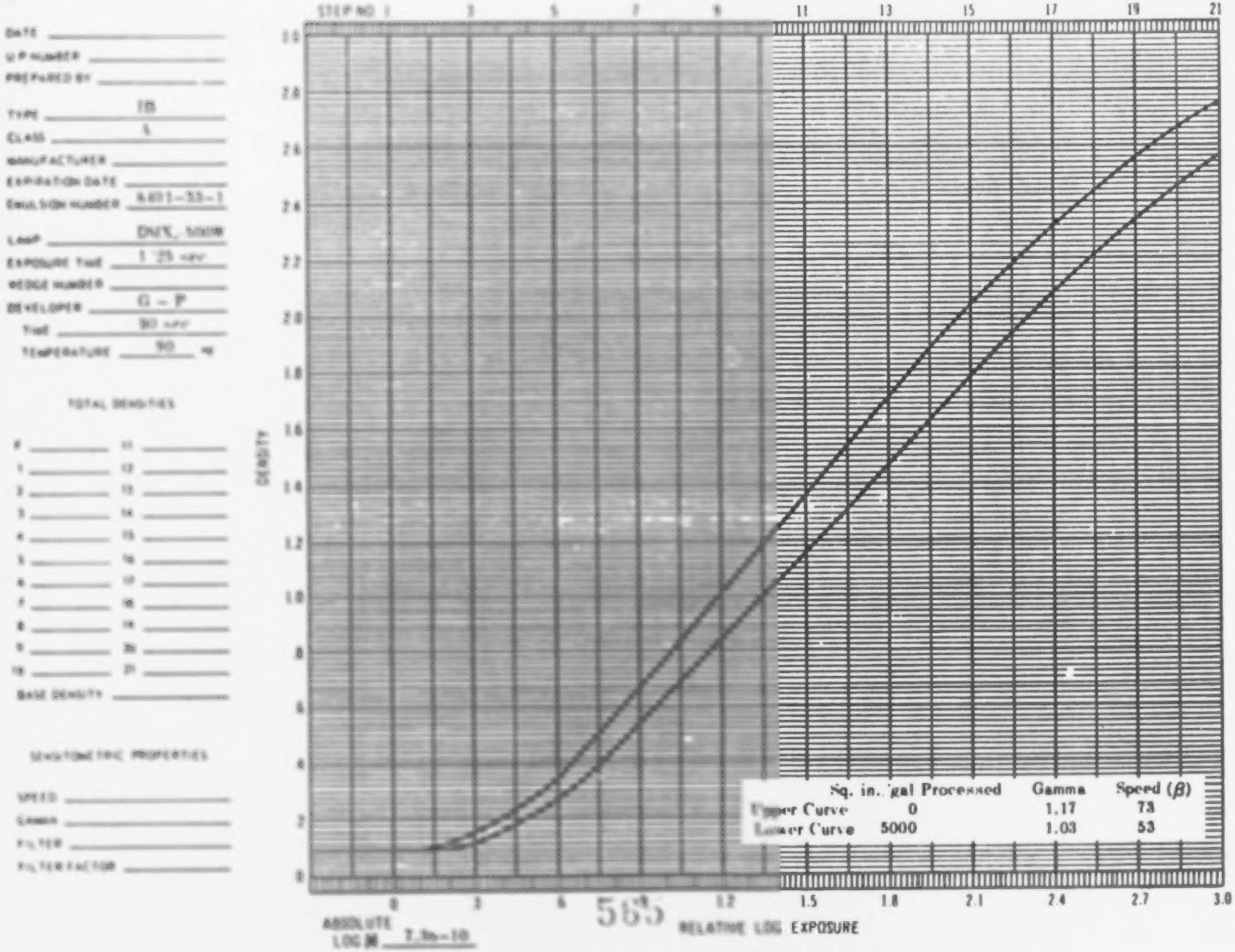
FILTER FACTOR



Wratten Filter	Log E Separation from Control Curve	Filter Factor
25	0.45	2.8
47	.77	5.9
58	.86	7.0

ABSOLUTE LOG E 7.52-10

Figure 3-4. Phenidone-Glycin filter factors.



DATE
U P NUMBER
PREPARED BY
TYPE 1B
CLASS 1
MANUFACTURER
EXPIRATION DATE
EMULSION NUMBER 6401-33-1
LAMP DMX, 500W
EXPOSURE TIME 1/25 sec
WEDGE NUMBER
DEVELOPER G – P
TIME 90 sec
TEMPERATURE 90 °F
BASE DENSITY
SPEED
GAMMA
FILTER
FILTER FACTOR
ABSOLUTE LOG E 7.3s–10

	Sq. in./gal Processed	Gamma	Speed (β)
Upper Curve	0	1.17	73
Lower Curve	5000	1.03	53

Figure 3-5. Exhaustion test (Phenidone-Glycin).

DATE 7-10-61

U P NUMBER ____

PREPARED BY ____

TYPE 1B

CLASS A

MANUFACTURER Kodak

EXPIRATION DATE ____

EMULSION NUMBER 8401-33-1

LAMP DMX, 500W

EXPOSURE TIME 1/25 sec

WEDGE NUMBER ____

DEVELOPER P – G, P.G. Aged

TIME 90 sec

TEMPERATURE 90 °F

TOTAL DENSITIES

F ____

1 ____

2 ____

3 ____

4 ____

5 ____

6 ____

7 ____

8 ____

9 ____

10 ____

11 ____

12 ____

13 ____

14 ____

15 ____

16 ____

17 ____

18 ____

19 ____

20 ____

21 ____

BASE DENSITY ____

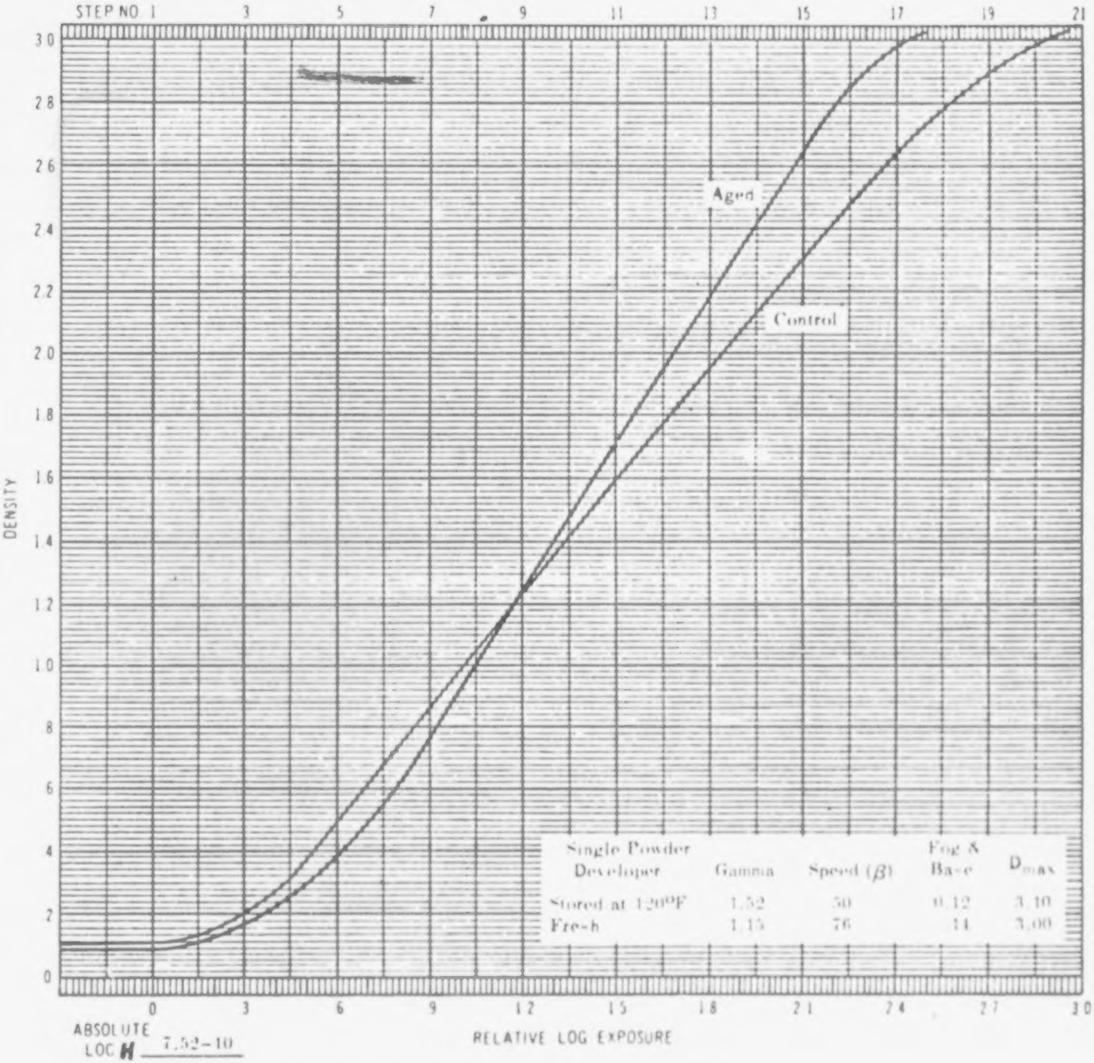
SENSITOMETRIC PROPERTIES

SPEED ____

GAMMA ____

FILTER ____

FILTER FACTOR ____



Single Powder Developer	Gamma	Speed (β)	Fog & Base	D_{max}
Stored at 120°F	1.52	50	0.12	3.10
Fresh	1.15	76	.14	3.00

Figure 3–6. Preparation from dry ingredients (Phenidone-Glycin).

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DATE ____________
U P NUMBER ____________
PREPARED BY ____________

TYPE IIB
CLASS A
MANUFACTURER Kodak
EXPIRATION DATE 10-60
EMULSION NUMBER 8401-58-11

LAMP 5500°K
EXPOSURE TIME 1/25 sec
WEDGE NUMBER ____________
DEVELOPER ____________
TIME ____________
TEMPERATURE ________ °F

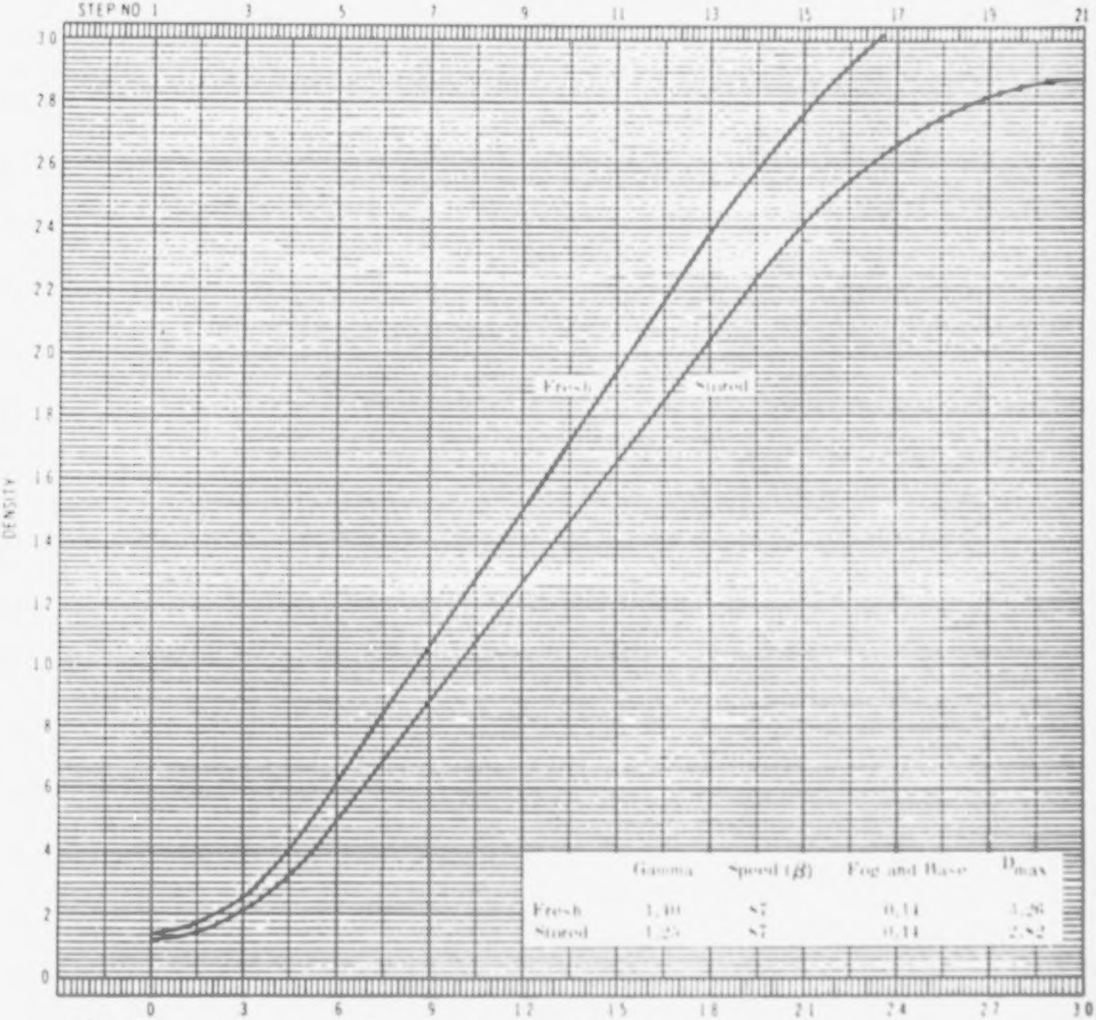
TOTAL DENSITIES

F		11	
1		12	
2		13	
3		14	
4		15	
5		16	
6		17	
7		18	
8		19	
9		20	
10		21	

BASE DENSITY ____________

SENSITOMETRIC PROPERTIES

SPEED ____________
GAMMA ____________
FILTER ____________
FILTER FACTOR ____________



	Gamma	Speed (β)	Fog and Base	D_{max}
Fresh	1.40	87	0.14	3.26
Stored	1.25	87	0.14	2.82

ABSOLUTE LOG E 7.52-10

RELATIVE LOG EXPOSURE

Figure 3-7. One-month storage of solution (Phenidone-Glycin).

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5. In figure 3-6, compare the gamma for the stored material against the controlled material.

6. How long can you store the developer solution in a stoppered container at a temperature that does not exceed 100°F without the developer solution deteriorating?

7. In figure 3-7, what was the most seriously affected property of the developed film?

722. Using figures 3-1, 3-2, 3-8, 3-9, and 3-10 as necessary, state the reason for comparing the performance of the Phenidone–Glycin developer against that of the individual active components.

Comparisons of Performance. The performance of the Phenidone–Glycin developer was checked against that of the individual active components to make sure that the properties of the developer are due to the combination and not to Glycin or Phenidone alone. All other ingredients of the developer are present in the quantities given for the Phenidone–Glycin developer. The results of these tests are shown in figure 3-8. Development by either Phenidone or Glycin is weak, and the properties of the recommended developer are dependent on the combination. The effect of the individual developers produces a curve well below that of the combination, indicating that Phenidone and Glycin form a superadditive combination.

For comparison, Armed Forces Developer No. 4 and D–19 were used to process Plus X Aerecon film at 90°F Armed Forces Developer No. 4 produced a very high contrast development (gammas of 12.0 or above), while D–19 was similar to the Phenidone–Glycin developer in its action. Curves for development by D–19 at 90° are shown in figure 3-9 and 3-10 (films of different emulsion number). By comparing these curves with those of figures 3-1 and 3-2, you can see that the Phenidone–Glycin combination gives a better balance of speed and gamma for optimum low-contrast development.

Exercises (722):

1. Why do you check the performance of the Phenidone–Glycin developer against that of the individual active components?

723. Using figure 3-11, state the modifications of different developers needed to determine whether a reason? able reduction in gamma can be obtained without a serious loss in speed.

Testing of Modifications. Since Armed Forces Developer No. 4 is used generally for processing at elevated temperatures, some modifications of this developer were investigated to see whether a reasonable reduction in gamma could be obtained without serious loss in speed. The only changes that could be made in such a formulation to reduce gamma are the addition of potassium bromide or the lowering of the pH. These changes should have no adverse effect on the stability of the developer. Both modifications were tried, and no appreciable lowering of gamma was noted. The results of the pH modification are shown in figure 3-11.

On the basis of these tests, it appears that the Phenidone–Glycin developer is lacking in only one respect; namely, stability to oxidation. However, it is believed that this weakness is directly responsible for the success of this combination as a low-contrast developer at elevated temperatures. At the beginning of this work, it was thought that the strong superadditivity of the Phenidone–hydroquinone and hydroquinone–Elon combinations was responsible for the high contrast produced on Plus X Aerecon film by developers such as D–19 and Armed Forces Developer No. 4. Accordingly, the search for weak superadditive combinations was initiated. Such combinations were found to produce undesirably low maximum densities. Developers with stronger superadditivity, such as D–19 and the Phenidone–Glycin combination, were found to give lower contrasts and lower maximum densities at 90°F than at 68°F. A fall-off in contrast and maximum density could be obtained at 68°F if the solutions of these developers were aerated prior to use. It therefore seems plausible that some oxidation phenomenon is responsible for the low-contrast development obtained at 90°F with the Phenidone–Glycin combination. This assumption can be substantiated, in part, by results obtained using water boiled and cooled under nitrogen for the preparation of the Phenidone–Glycin developer. Under these conditions, maximum densities higher by about 0.2 density unit could be obtained at 90°F. The oxidation effects appear to take place during the preparation of the solution. Once the solution is prepared and stored in a stoppered container or used in a processing system where the oxygen access is minimized, the deterioration of the developer by oxidation is quite slow.

Several variations in the composition of the developer were tried. Increases in pH increased the speed. These variations in the composition of the developer also increased the contrast and reduced the oxidation stability of the developer. Variations in the bromide ion concentration had little effect on the observed development. This could be predicted from the exhaustion test on the developer. However, it did tend to decrease its storage stability. Addition of hydroquinone (1 g/liter) to the developer increased the gamma sharply. In view of these observations, it was felt that the initial formulation would

DATE ________
U.P. NUMBER ________
PREPARED BY ________

TYPE IB
CLASS A
MANUFACTURER Kodak
EXPIRATION DATE ________
EMULSION NUMBER 8401-33-1

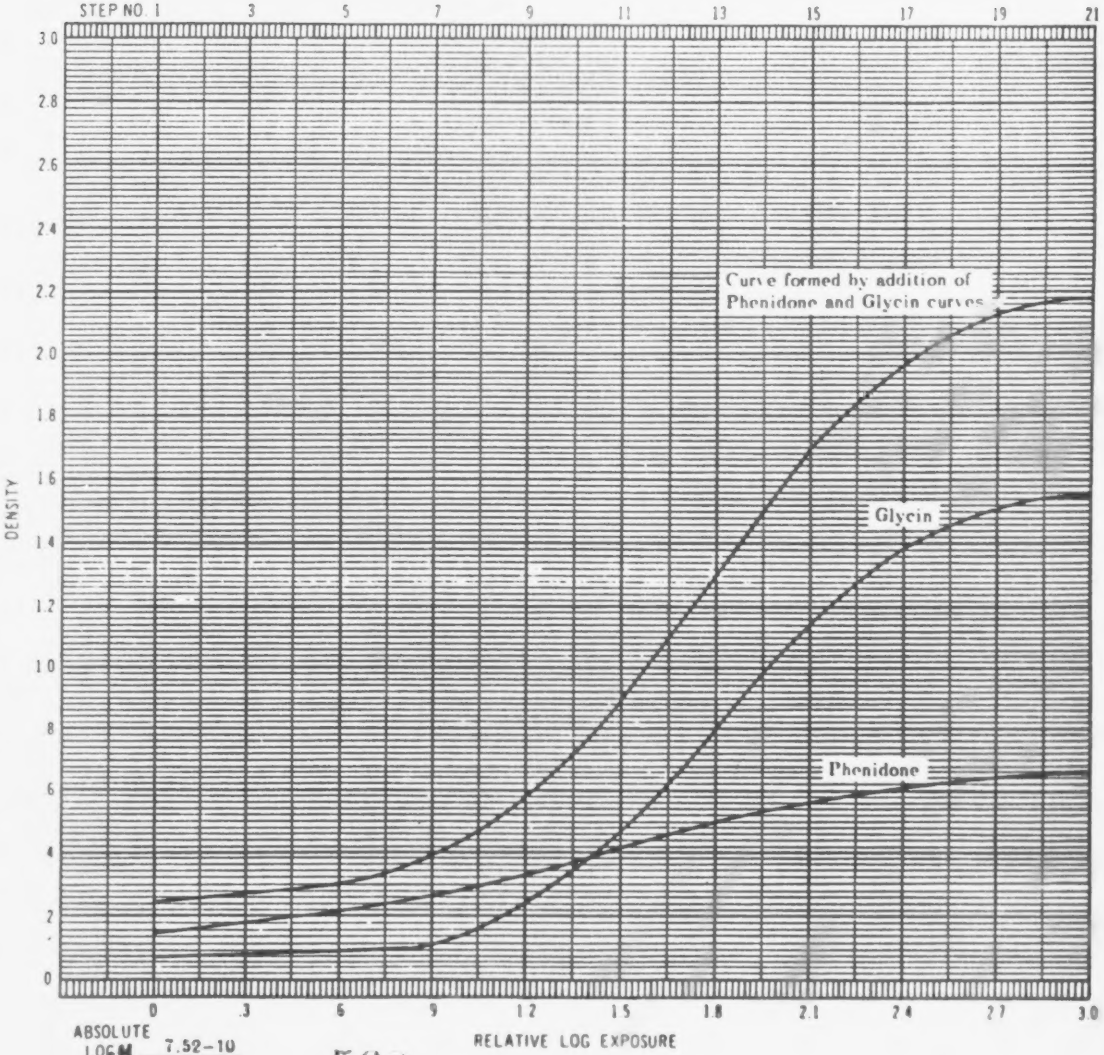
LAMP 5500°K
EXPOSURE TIME 1/25 sec
WEDGE NUMBER ________
DEVELOPER ________
TIME 2 min
TEMPERATURE 90 °F

TOTAL DENSITIES

F ________
1 ________
2 ________
3 ________
4 ________
5 ________
6 ________
7 ________
8 ________
9 ________
10 ________
11 ________
12 ________
13 ________
14 ________
15 ________
16 ________
17 ________
18 ________
19 ________
20 ________
21 ________
BASE DENSITY ________

SENSITOMETRIC PROPERTIES

SPEED ________
GAMMA ________
FILTER ________
FILTER FACTOR ________



ABSOLUTE LOG H 7.52-10

Figure 3-8. **Separate Phenidone and Glycin results.**

DATE ____________

U P NUMBER ____________

PREPARED BY ____________

TYPE 1B

CLASS A

MANUFACTURER Kodak

EXPIRATION DATE 10-60

EMULSION NUMBER 8401-58-11

LAMP 5500°K

EXPOSURE TIME 1/25 sec

WEDGE NUMBER ____________

DEVELOPER ____________

TIME ____________

TEMPERATURE ________ °F

TOTAL DENSITIES

F ________
1 ________
2 ________
3 ________
4 ________
5 ________
6 ________
7 ________
8 ________
9 ________
10 ________
11 ________
12 ________
13 ________
14 ________
15 ________
16 ________
17 ________
18 ________
19 ________
20 ________
21 ________

BASE DENSITY ____________

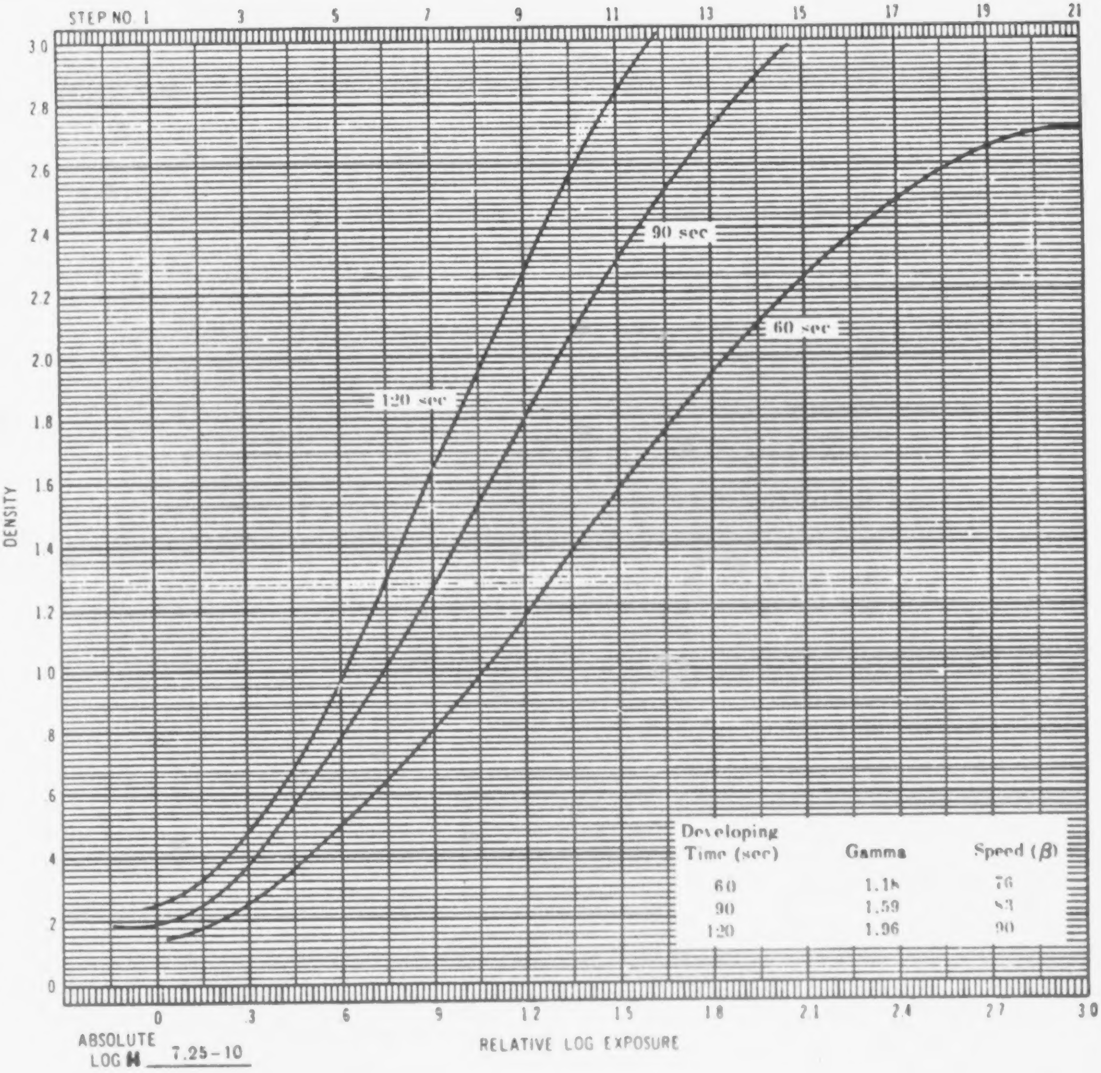
SENSITOMETRIC PROPERTIES

SPEED ____________

GAMMA ____________

FILTER ____________

FILTER FACTOR ____________



Developing Time (sec)	Gamma	Speed (β)
60	1.18	76
90	1.59	83
120	1.96	90

Figure 3-9. D-19 at 90°F.

DATE ____________

U P NUMBER ____________

PREPARED BY ____________

TYPE IB

CLASS A

MANUFACTURER Kodak

EXPIRATION DATE ____________

EMULSION NUMBER 8401-33-1

LAMP 5500°K

EXPOSURE TIME 1/25 sec

WEDGE NUMBER ____________

DEVELOPER D-19

TIME ____________

TEMPERATURE ________ °F

TOTAL DENSITIES

F ________ 11 ________

1 ________ 12 ________

2 ________ 13 ________

3 ________ 14 ________

4 ________ ________

5 ________ 16 ________

6 ________ 17 ________

7 ________ 18 ________

8 ________ 19 ________

9 ________ 20 ________

10 ________ 21 ________

BASE DENSITY ____________

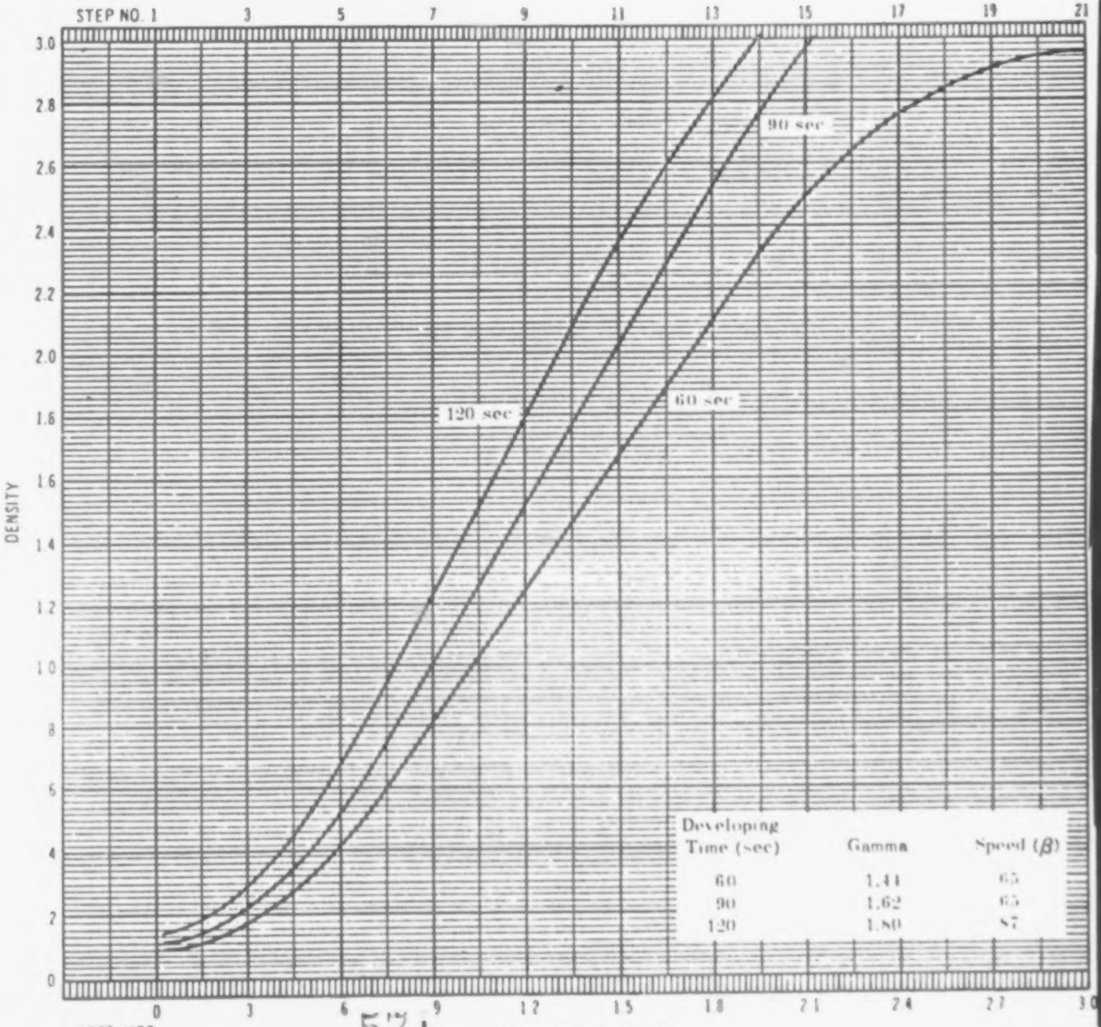
SENSITOMETRIC PROPERTIES

SPEED ____________

GAMMA ____________

FILTER ____________

FILTER FACTOR ____________



Developing Time (sec)	Gamma	Speed (β)
60	1.44	65
90	1.62	65
120	1.80	87

ABSOLUTE LOG H 7.52-10

Figure 3-10. D-19 at 90° F. (emulsion change).

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DATE 5-4-61

U P NUMBER

PREPARED BY D.E.

TYPE 1B

CLASS A

MANUFACTURER Kodak

EXPIRATION DATE 10/60

EMULSION NUMBER 8401-58-11

LAMP 5500°K

EXPOSURE TIME 1/25 sec

WEDGE NUMBER

DEVELOPER A.F. No. 4

TIME 90 sec

TEMPERATURE 90 °F

TOTAL DENSITIES

F
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

BASE DENSITY

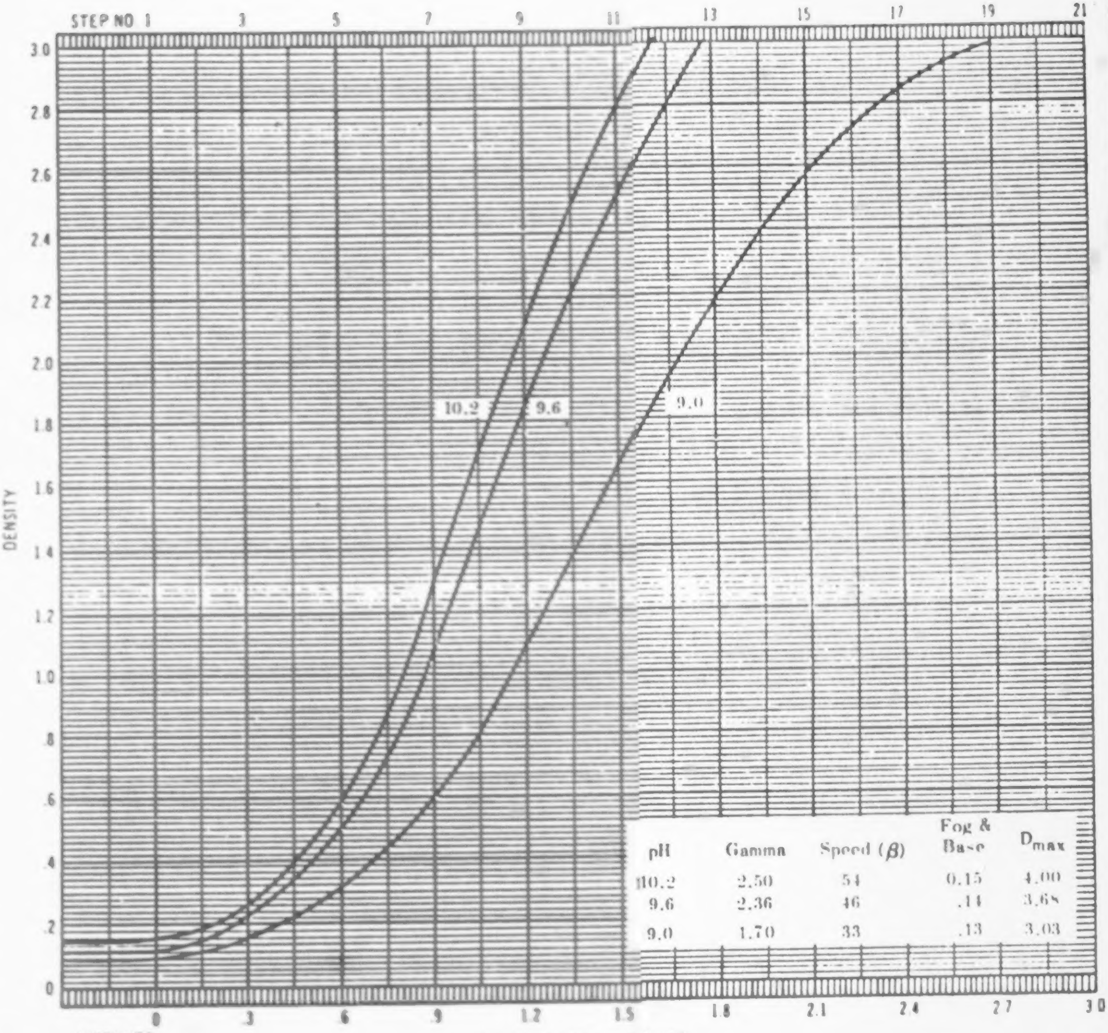
SENSITOMETRIC PROPERTIES

SPEED

GAMMA

FILTER

FILTER FACTOR



pH	Gamma	Speed (β)	Fog & Base	D_{max}
10.2	2.50	54	0.15	4.00
9.6	2.36	46	.14	3.68
9.0	1.70	33	.13	3.03

ABSOLUTE LOG E 7.52-10

Figure 3-11. AF Developer No. 4 (pH changes).

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best fit the requirements. In comparison with developers now in use for Air Force processing requirements on Plus X Aerecon aerial rollfilm, the initial formulation provides (at 90°F) the lowest contrast range for the same level of exposure index.

Exercises (723):

1. List the two modifications in the Armed Forces Developer No. 4 generally used for processing at elevated temperatures that showed no appreciable lowering of gamma.

2. On the basis of test, what seems to be lacking in a Phenidone–Glycin developer?

3. What were the results for D–19 and Armed Forces Developer No. 4 with weak superadditive combinations?

4. What were the test results with developers with stronger superadditivity, such as D–19 and the Phenidone–Glycin combination?

5. What is responsible for the low-contrast development obtained at 90°F with the Phenidone–Glycin combination?

3-1. New Standards of Quality and Performance

Air Force reconnaissance photography has grown from shooting pictures from captive balloons and low-flying aircraft to its present state requiring photographs taken from tremendously fast vehicles, flying at extremely high altitudes. Now, since the scale of aerial photographs is so small, you must exercise critical control over all stages of processing. Otherwise, you may lose the important detail contained in the small images of your photographs. Your first effort must be to create in your processing laboratory an environment that does not destroy the intelligence capability of your film. To meet the demands of Air Force photography for extreme detail in small images, you must exercise precise and exacting control. This can only be done by maintaining strict discipline in clean room facilities. This section covers the design of controlled environment facilities and presents guidelines for maintaining and operating such facilities. Also, we describe various types of clean rooms and work areas and discuss the discipline you must observe while working in them.

724. As designated by the Air Force; list and define the types of clean rooms; state the criterion that governs a clean room, and the airborne contamination control requirements for an AF clean work station (AFCWS); and identify the person who sets the limits for controlled areas.

Type of Clean Rooms. From a practical standpoint, a clean room contains contamination in amounts so small that the operation within the room is not deleteriously affected. Because the operators and operation generate contamination within an enclosure, it is impracticable to make any room completely clean and to maintain cleanliness. The problem, then, is to decide how much contamination you can live with and adopt control procedures to help you achieve the degree of cleanliness you need. In the Air Force, clean rooms are designated as controlled areas, standard clean rooms, and clean workstations.

Controlled areas. A controlled area is any workspace, room, shop, or facility requiring cleanliness beyond normal housekeeping. It is not to be classified as a clean room. An area in which clean room equipment is repaired or overhauled is a controlled area. In such an area, a high degree of cleanliness must be maintained, but strict environmental control is not necessary. Ordinarily, the ambient temperature is controlled so that it will not exceed 80°F. However, your operation might necessitate more stringent control. Moreover, you might require other limits short of clean room conditions. When this is the case, these limits should be set and maintained. If the limits you set approach those of a standard clean room, you no longer have a controlled area, and you should designate the facility as an AF clean room.

Since the requirements for controlled areas are so flexible, no specific directions for establishing them are given here. Your installation sets the limits for your controlled areas according to your own requirements.

Standard clean rooms. Any room, shop or facility in which environmental conditions are positively controlled is designated as an AF standard clean room (AFSCR). In photoprocesing laboratories, rooms or laboratories used for preinspection of film, film processing, printing of duplicate negatives and positives, sensitometric evaluation of sensitized materials, final inspection, or packing and shipping may require the exacting controls of an AF standard clean room. The deciding factor can be stated in terms of the resolution capabilities of the equipment and materials involved in the process. For example, photographic reproduction and interpretation activities employing optical equipment capable of resolving 600 or more lines per millimeter might require a particle size limit of about 0.84 micron. However, clean room limits should not be stated solely in terms of resolution. Any other meaningful measurement of the capability of the system can be used as a basis for establishing clean room requirements.

The criterion should always be governed by the quality of the product being produced.

Clean work stations. Any contamination-controlled work space designed to insure a high degree of cleanliness in the immediate vicinity of a task or an operation can be called an AF clean work station (AFCWS). Ordinarily, the requirements for airborne contamination control are higher for AFCWSs than for AFSCRs.

Exercises (724):

1. List the three types of clean rooms designated by the Air Force.

2. Define a controlled area, and give an example.

3. Who sets the limits for controlled areas?

4. Define a standard clean room and give an example of an AF standard clean room (AFSCR).

5. What governs the criterion of a clean room?

6. Define a clean work station.

7. Compare the airborne contamination control requirements for an AF clean work station (AFCWS) with those of an AF standard clean room (AFSCR).

725. State the control standards maintained for clean rooms and work stations.

Controls for AFSCRs and AFCWSs. Based upon the operation and the quality of the product, clean rooms and work stations should be designed so that certain control standards can be maintained. Actually two sets of standards are needed. The *first* set is met when the environmental control systems are operating but no work is being done; whereas the *second* set is met when the environmental control systems are operating during production. The recommended standards follow.

Temperature tolerances in ambient air. The air-conditioning system in an AFSCR must be able to provide a temperature range of 67 to 77°F and be able to control the room rate change to 2.5°F per hour when no work is being done. This condition must be met regardless of seasonal variations of the temperature and humidity of the ambient air. Of course, the average working temperatures in imagery production clean rooms are determined by the requirements of the operation taking place.

When work is being done in an AFSCR, the air-conditioning system must still provide the 67 to 77 °F temperature range but need only control the room rate of change to 4.0°F per hour.

Humidity tolerances. When no work is being done, 40 percent relative humidity is the allowable maximum for an AFSCR; no minimum is set. When work is being done, the maximum relative humidity is 45 percent, with the minimum dictated by the requirements of the process.

Contamination limits. In an AFSCR at rest, the air filtration system should limit particles per cubic foot (p/cf) to 20,000 particles or less, 0.5 micron and larger, with not more than 4,000 p/cf, 1.0 micron and larger. These two points will give the slope of particle size-distribution relationship which is established in Report 17.0002.04.01, Size Distribution Relationships for Airborne Particulate Matter, MAMES, Olmsted AFB, PA.

When the room is being operated, the particle count and size requirement must not be more than 100,000 p/cf, 0.5 micron size and larger, with not more than 20,000 p/cf, 1.0 micron size and larger, at the working level.

The air filtration method for an AFCWS should limit the p/cf to not more than 100 p/cf, 0.5 micron size and larger at rest. This condition should be maintained throughout the entire work station upstream of the workpiece.

For a clean work station in operation, the particle count may not be more than 1,000 p/cf, 0.5 micron size and larger. In this volume, we use the terms "particulate contamination" and "particulate matter" to describe all contaminants that are found in imagery production laboratories. These include dust, lint, vapor, chemicals, bacteria, spores, and gaseous substances.

Air handling. The air-handling system should be able to change the air in an AFSCR approximately 20 times per hour. Also, it should maintain a positive pressure differential of 0.10 inch of water between the clean room and the contaminated area. A minimum positive pressure differential of 0.05 inch of water must be maintained between the uncontaminated section and the semicontaminated section. And a minimum positive pressure differential of 0.01 inch of water must be maintained between the semicontaminated section and the locker area. The pressure differentials measured with the entry door closed and have an outflow of air from the more critical to the less critical areas.

For an AFCWS, a minimum velocity of 100 feet per minute of laminar airflow is to be maintained throughout the workstation. This condition may be altered if your operation requires it or if air filtration standards can be met at the altered velocity (fig. 3-12).

Exercises (725):

1. What are the two sets of standards that are maintained for clean rooms and work stations?

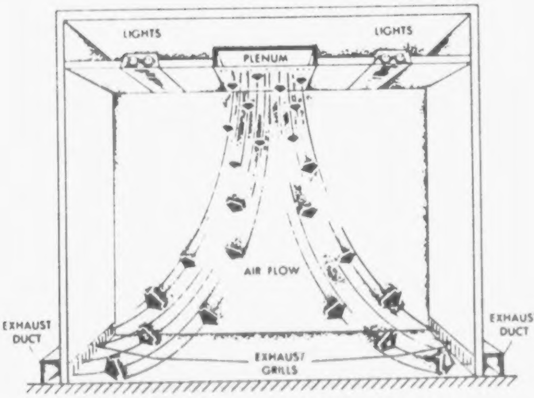

Figure 3–12. Conventional clean room.

2. What is the temperature tolerance for the air-conditioning system in an AFSCR?

3. What is the humidity tolerances for an AFSCR when no work is being done?

4. In an AFSCR at rest, what should the air filtration system limit its particles to?

5. Define "particulate contamination" and list examples.

3-2. Compatability of New Materials with the Existing Processes and Equipment

Any imgagery production laboratory, regardless of the level of the mission, must have the capability of providing the chemistry to its processing machines without transporting chemicals or solutions through the room. All processing solutions must be piped from the chem-mix room through a system of flowmeters to the processing machines.

726. Using figures 3-13 to 3-16 as necessary, state the capability of a facility to provide chemical services to the processing machines, and list the processing machines most commonly in use in an environmentally controlled laboratory.

Chemical Services and Processing Machines in an Environmentally Controlled Laboratory. Figure 3-13 shows an operating control panel serving an extensive imagery production facility. The technician controls the flow of chemicals to a processing machine while in voice communication with the processing technician. The flowmeters and temperature gauges show the status of the various machines in operation. The warning lights indicate when the process is functioning properly and alert the technician when something goes wrong. Replenisher solutions should be fed into the system in a similarly controlled manner. The replenishment and control over solution temperatures are usually conducted, under close scrutiny, in heat exchange tanks incorporated in the circulating system of the processor. This arrangement works well for all processors, whether they are spray or immersion types. The processors should be provided with a quick-fill capability, as well as a drain-and-flush capability, so that the dirtiest part of the chemical service can be accomplished without contaminating the clean area. The state of cleanliness to be maintained in the chem-mix area is understandably lower than that required for the processing areas, but every safeguard against introducing contamination into the processing system must be observed. Personnel should wear protective clothing (not clean room clothing) and should not smoke, eat, or drink in the chem-mix area. Figure 3-14 shows a chem-mix technician pouring dry chemicals into a hopper which flushes the chemical into the mixing tank. All storage tanks should be equipped with covers, as figure 3-15 shows, to prevent foreign matter from accidentally falling into the tanks. Chem-mix personnel should be trained in the imagery production field and should be capable of rotating with technicians in other areas.

In imagery production laboratories, processing is generally confined to the development of black-and-white original negatives and to the development of duplicate negatives and film positives. While some laboratories engaged in imagery production also make prints on paper stock, the requirement for paper prints is somewhat limited, and, aside from cautioning that paper stock should never be handled in the printing and processing areas where particulate contamination cannot be tolerated, the following paragraphs are limited to film processing.

When processing original negatives; you must be right the first time, otherwise, irreplaceable information may be lost. Usually there is a great urgency to produce the highest quality negative in the shortest possible time, although the two needs are not compatible. Still, your mission requirements must be met, and your responsibility is to produce a product that meets them. You always exercise as much control as possible and still get the product out on time. If you are working in a completely environmentally controlled facility, start as clean as possible, work as carefully as possible, and clean up again after you finish.

Original negative material that must be processed at speeds of about 60 feet per minute is generally given to straight processing in such machines as the HTA3, HTA3C, and HTA3CM. The processors are covered in detail in AFM 52-1 (obsolete but used as a training manual); but where some speed can be sacrificed in the interest of quality, original negative is often given interrupted processing. In the recent past, interrupted processing required the use of two separate processing machines. The purpose of the first machine was to give the basic development, to arrest and stabilize the film, and to dry it. After the first development, the film was inspected by means of infrared radiation and an

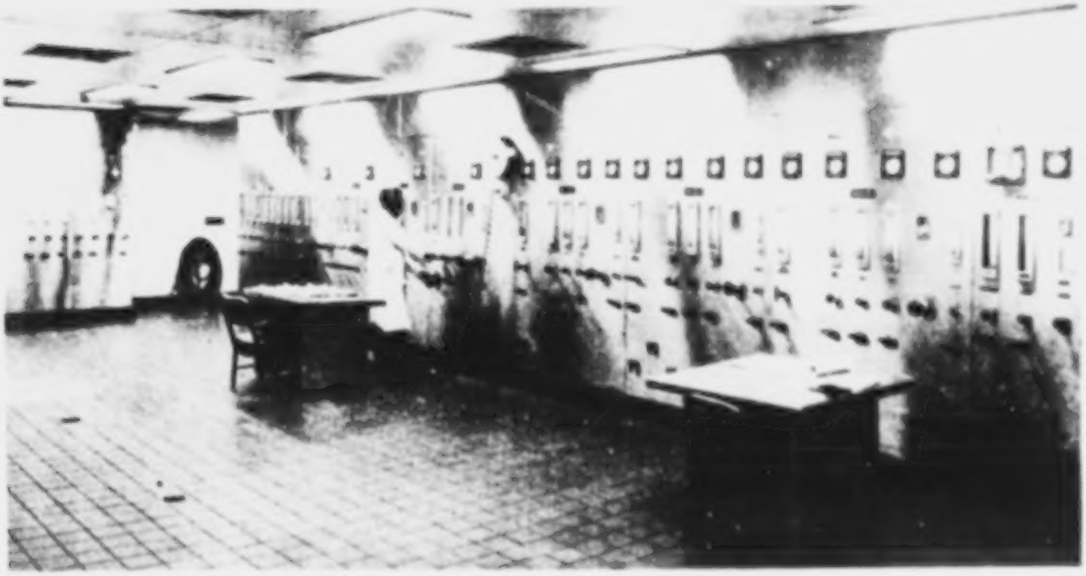

Figure 3-13. Chem-mix control panel.

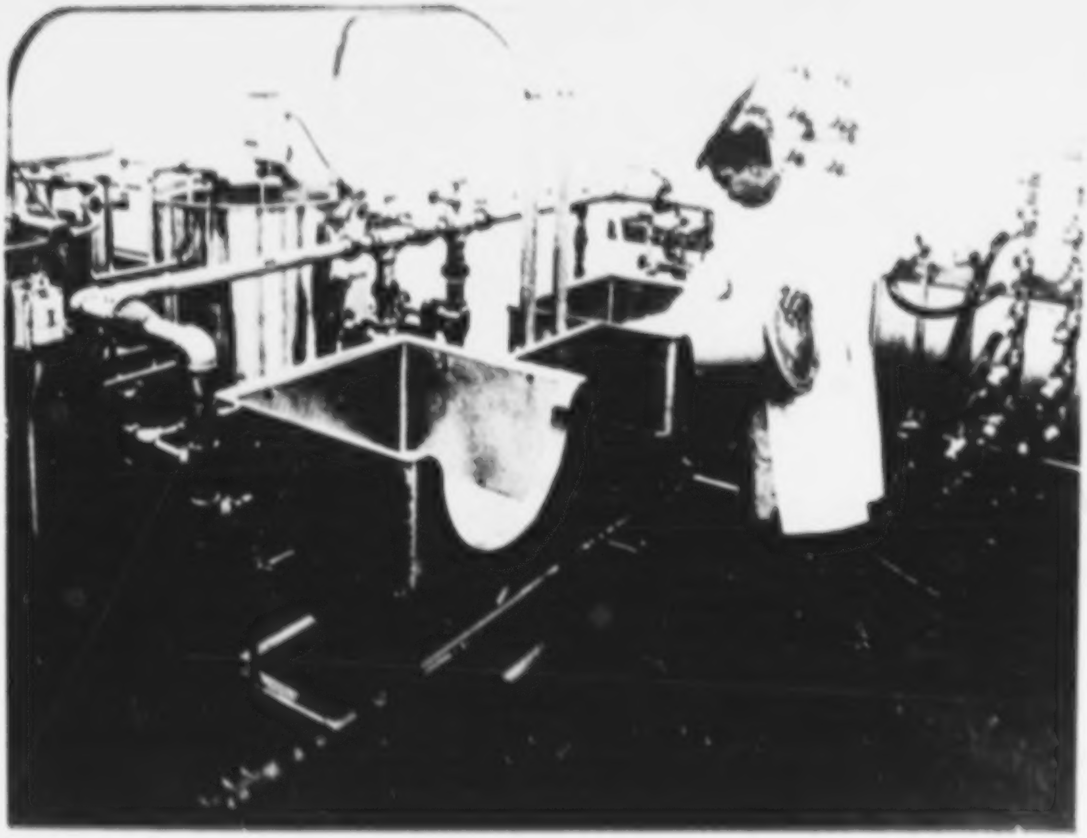

Figure 3-14. Chemical hoppers and mixing tanks.

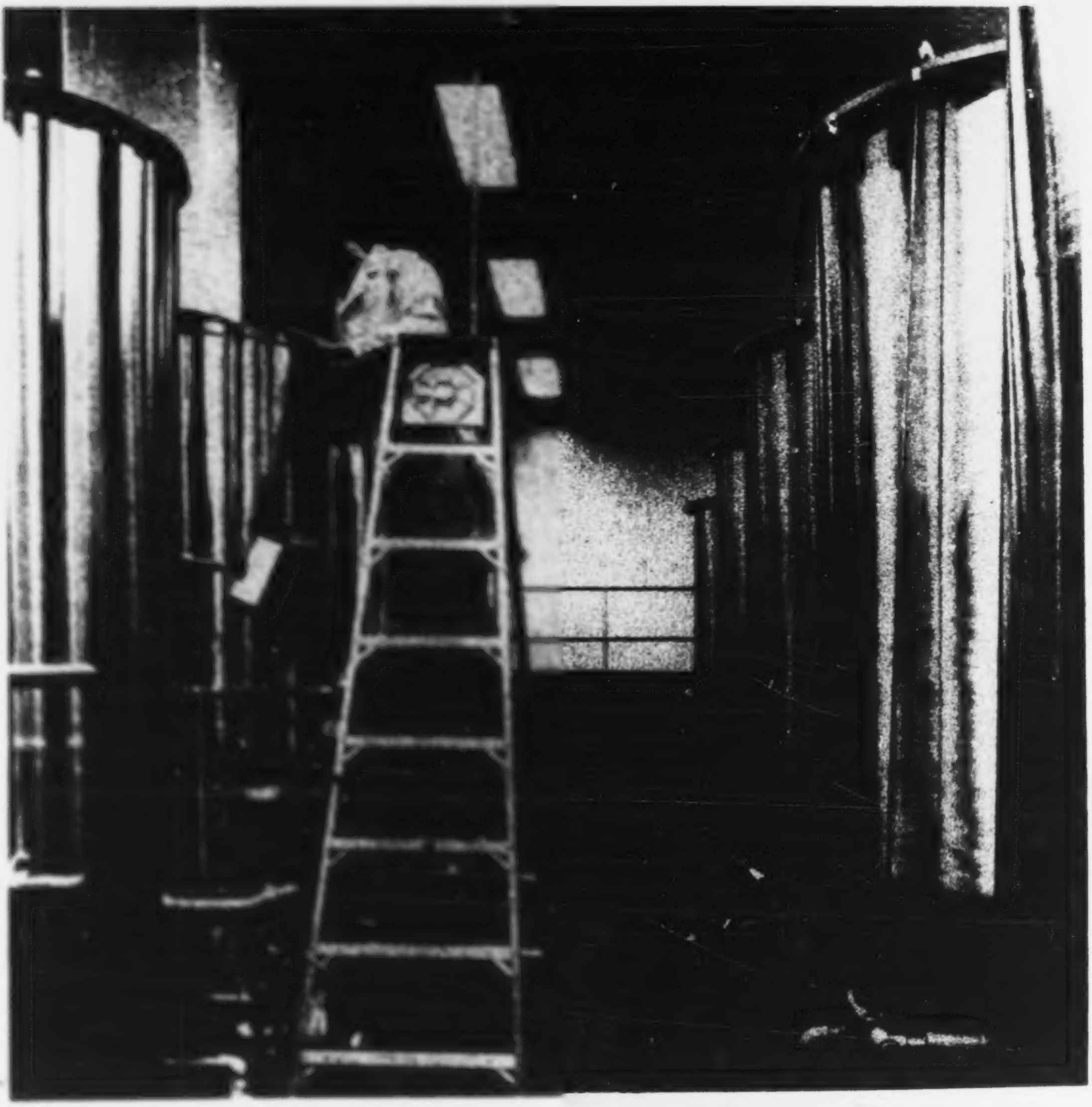

Figure 5-15. Stainless steel storage tanks.

IR converter tube, and if additional development was needed, it was programmed. The second processing machine provided either the required additional development, or simply a fix, wash, and dry cycle if no further development was needed. Now, all of these stages can be done in one machine. Such a machine, illustrated in figure 3-16, is the Trenton film processor, made by Eastman Kodak Company. This machine develops the film in the first section and gives it a quick stop bath to interrupt the process of development. The film passes through the central scanning section, where it is "looked at" and evaluated, either automatically or visually, and the additional treatment is prescribed. The film then passes through the final section to completion. As long as the original negative is at all usable, it is never discarded. Its value for informational purposes is proportional to its quality, and utmost quality must always be our goal. Whether good or bad, the original negative is all there is, and it must be used. On the other hand, if a duplicate negative or a film positive does not meet the required high standard, it is discarded, and the work is done over. However, make-overs are costly in both time and money. Consequently, this type of work is done in environmentally controlled laboratories under precision processing conditions.

The processing machines most commonly used are the HTA2, HTA3, HTA3C, and the HTA3CM by Houston-Fearless and the Dalton film processor by Eastman Kodak. These machines are capable of high-quality production and are suitable for use in environmentally controlled rooms. They are enclosed, and all peripheral equipment is outside of the clean room area. In a clean, precision operation, these machines are serviced just as the original negative processors are serviced.

Exercises (726):

1. What, on the control panel, shows the status of the processing machines in operation?

2. Where are the replenishment and control over solution temperatures usually conducted?

3. In order that the dirtiest part of the chemical service can be accomplished without contaminating the clean area, what are the processors provided with?

4. List the processing machines most commonly used in an environmentally controlled laboratory.

3-3. Test Reports

The test report is comprehensive in that it covers an entire investigation, sometimes arriving at conclusions, at other times adding recommendations to the conclusions. The report recites facts and conclusions which lead to the solution of some problem.

The length of the report varies, depending on the nature of the problem. It may treat one problem or a host of problems.

727. State the procedures used to prepare a test report.

Preparing a Report. When preparing a report, the following procedures are generally followed:

The format. The format is the physical makeup of the test report and generally is made up to include:

a. Cover and outside title (fig. 3-17).
b. Inside title page (fig. 3-18).
c. Foreword (fig. 3-19).
d. Summary (fig. 3-20).
e. Table of contents (fig. 3-21).
f. Illustrations (fig. 3-22).
g. Tables (fig. 3-23).
h. Abbreviations (fig. 3-24).
i. Introduction.
j. Purpose of IOTEE.
k. Methods of accomplishment.
l. Results and discussion.
m. Conclusions.
n. Recommendations.

The covers can range from still fiber covers with built-in staples to hardboard ledger bindings, equipped with removable screws that can be expanded to accommodate several inches of thickness.

The title page gives the reader the first impression of the content of the report. The following list shows the items which should appear on title pages:

a. The project or code number assigned to the report.
b. The title of the report.
c. The name of the agency issuing the report.
d. The date of publication (or completion).
e. The name and official position of the person chiefly responsible for preparing or supervising the report.
f. The signature, typed name, and official position of the person authorized to approve the report.
g. The address of the issuing agency.

Table of Contents. The table of contents, by means of headings and subheadings, shows the relationship of the topics that are treated within the report. The topics are listed on the same sequence as they appear on the main report and have the same wording in both places. The table of contents tells the reader at a glance the exact page on which every listed topic begins in the text. The contents maintain a bird's-eye view that is not cluttered with details. The contents are preceded by a frontispiece, a foreword, and the summary. A sample of the table of contents is seen in figure 3-21.

Illustrations and tables. Reports that contain illustrations and tables should list them on separate pages immediately following the table of contents page. The illustrations include graphs, drawings, photographs, maps, etc. A table is any data arranged in columns (vertical) and rows

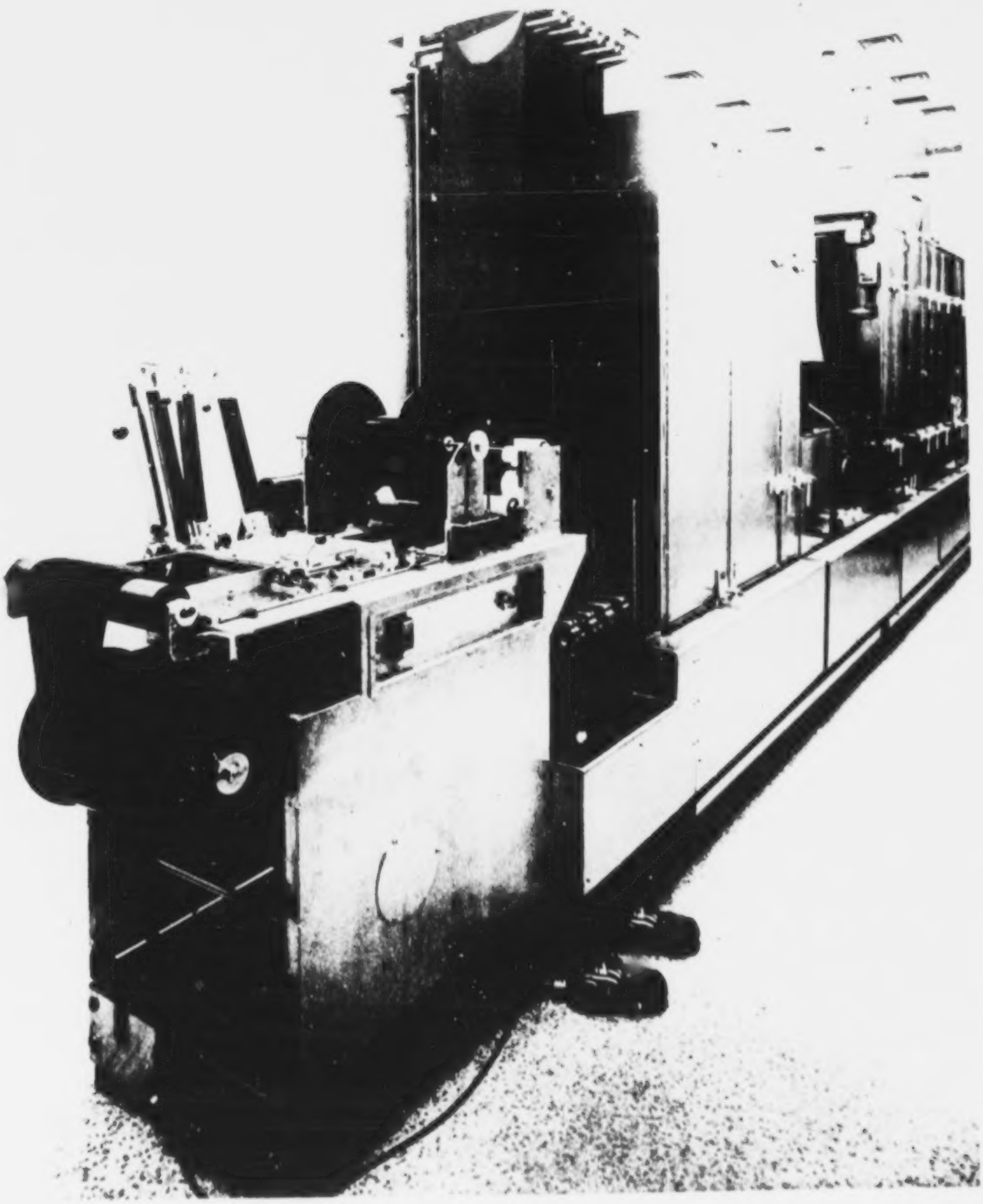

Figure 3–16. Trenton film processor.

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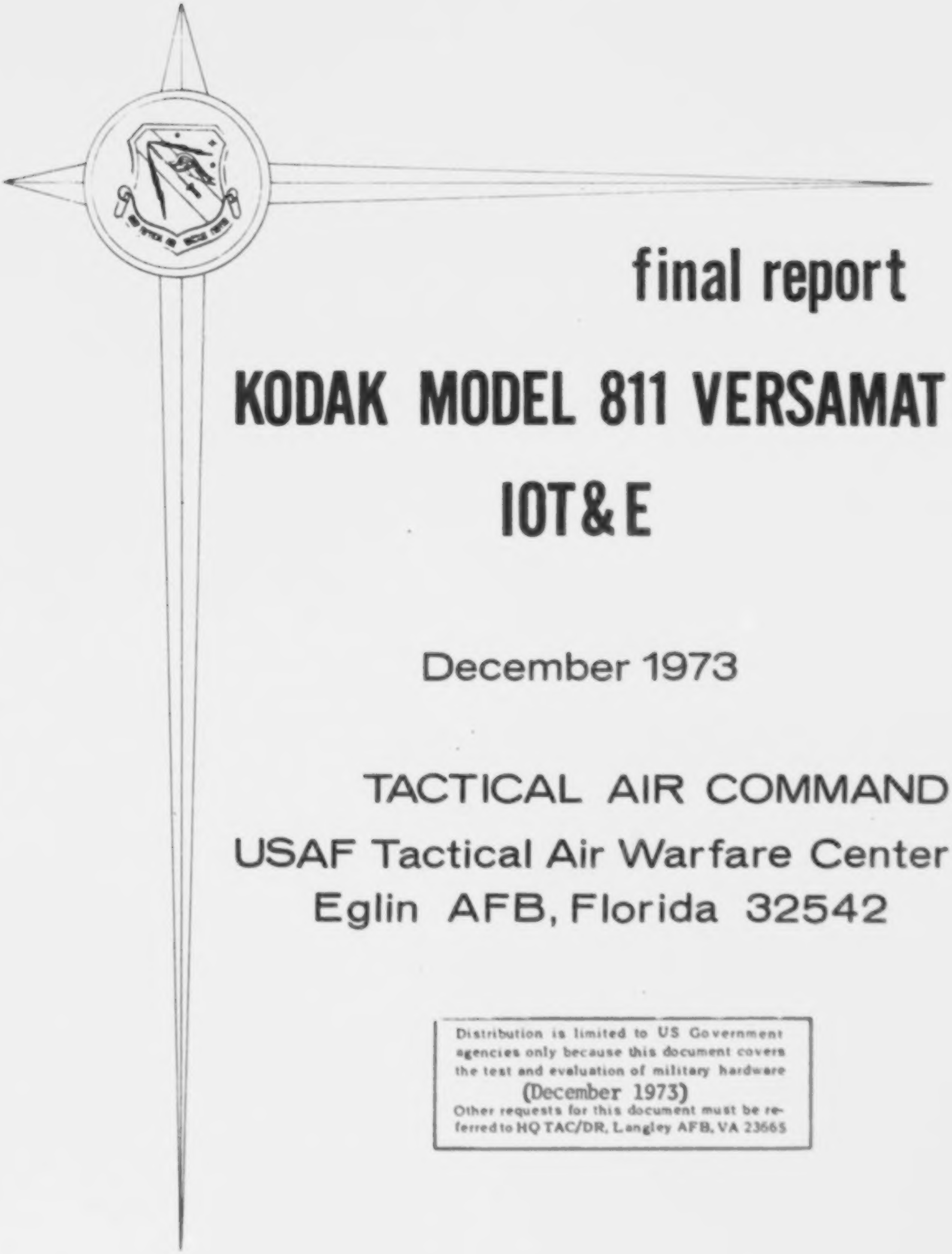


final report

KODAK MODEL 811 VERSAMAT

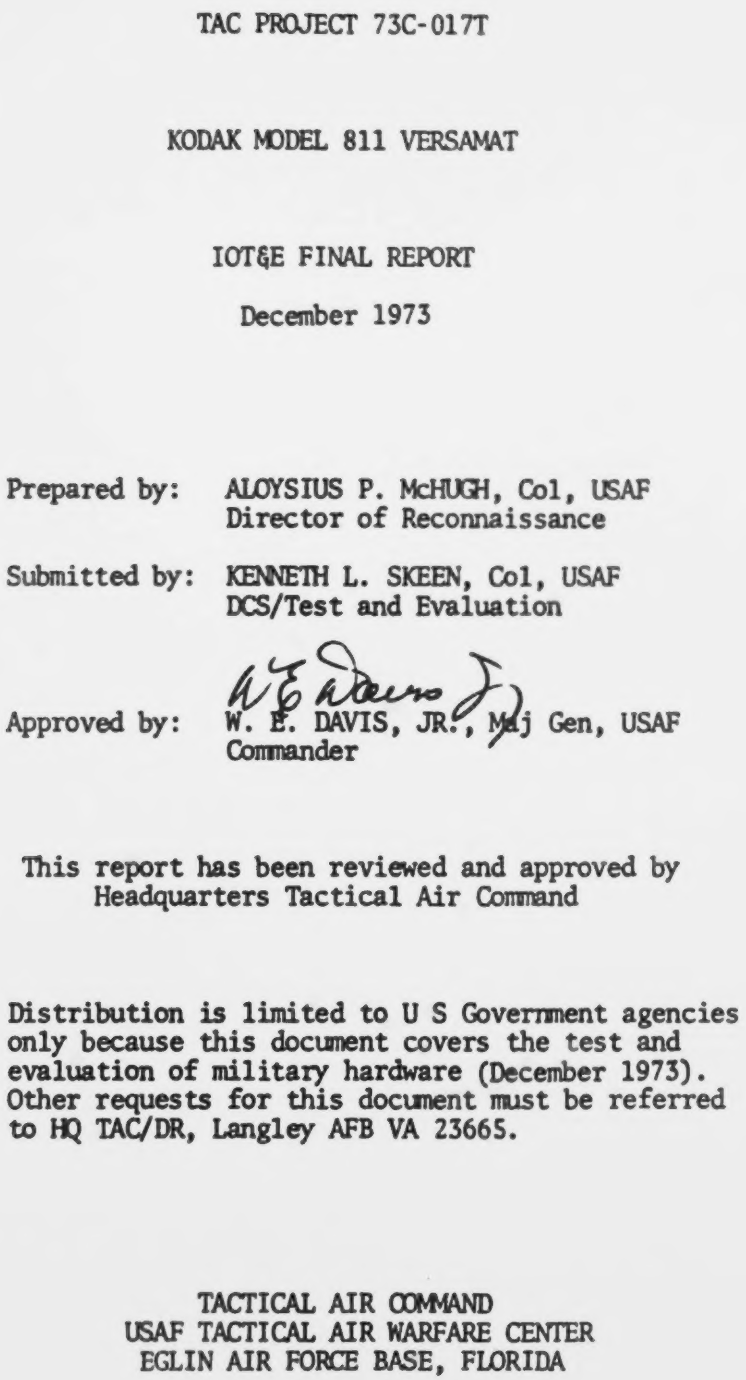
IOT&E

December 1973

TACTICAL AIR COMMAND
USAF Tactical Air Warfare Center
Eglin AFB, Florida 32542

Distribution is limited to US Government agencies only because this document covers the test and evaluation of military hardware
(December 1973)
Other requests for this document must be referred to HQ TAC/DR, Langley AFB, VA 23665

Figure 3-17. Cover and outside title page.



TAC PROJECT 73C-017T

KODAK MODEL 811 VERSAMAT

IOT&E FINAL REPORT

December 1973

Prepared by: ALOYSIUS P. McHUGH, Col, USAF
Director of Reconnaissance

Submitted by: KENNETH L. SKEEN, Col, USAF
DCS/Test and Evaluation

W E Davis Jr

Approved by: W. E. DAVIS, JR., Maj Gen, USAF
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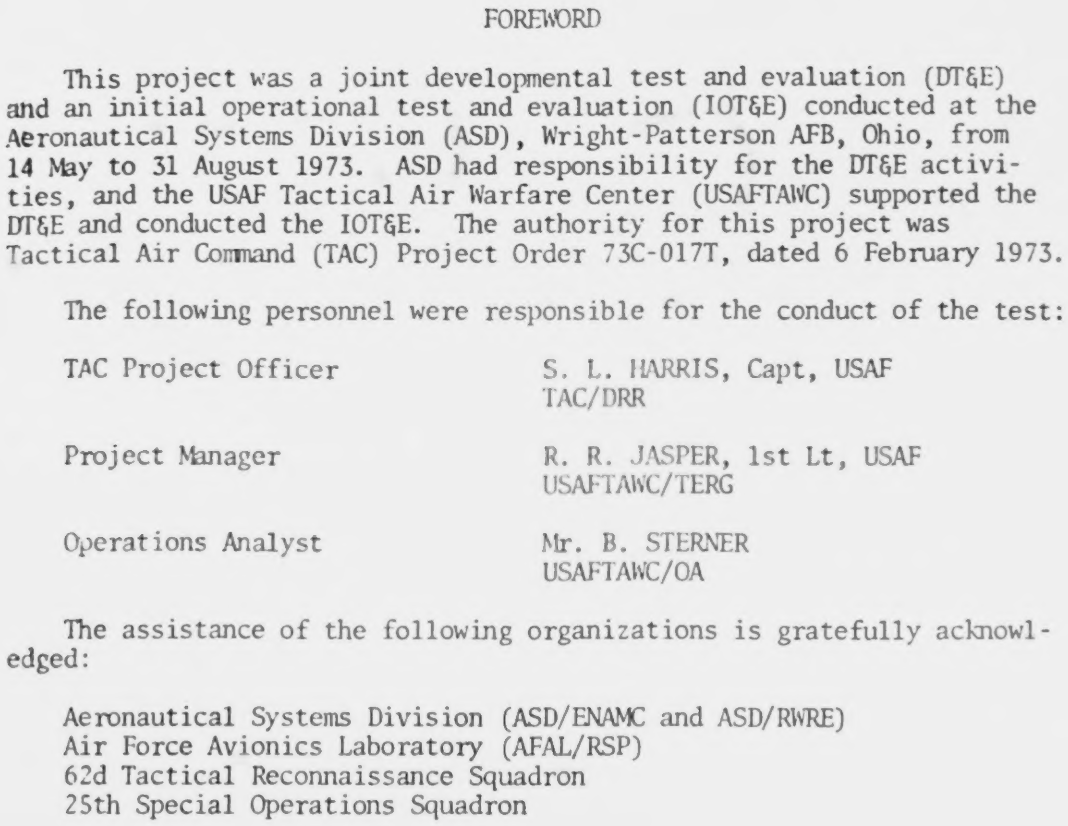
This report has been reviewed and approved by
Headquarters Tactical Air Command

Distribution is limited to U S Government agencies only because this document covers the test and evaluation of military hardware (December 1973). Other requests for this document must be referred to HQ TAC/DR, Langley AFB VA 23665.

TACTICAL AIR COMMAND
USAF TACTICAL AIR WARFARE CENTER
EGLIN AIR FORCE BASE, FLORIDA

Figure 3-18. Inside title page.



FOREWORD

This project was a joint developmental test and evaluation (DT&E) and an initial operational test and evaluation (IOT&E) conducted at the Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio, from 14 May to 31 August 1973. ASD had responsibility for the DT&E activities, and the USAF Tactical Air Warfare Center (USAFTAWC) supported the DT&E and conducted the IOT&E. The authority for this project was Tactical Air Command (TAC) Project Order 73C-017T, dated 6 February 1973.

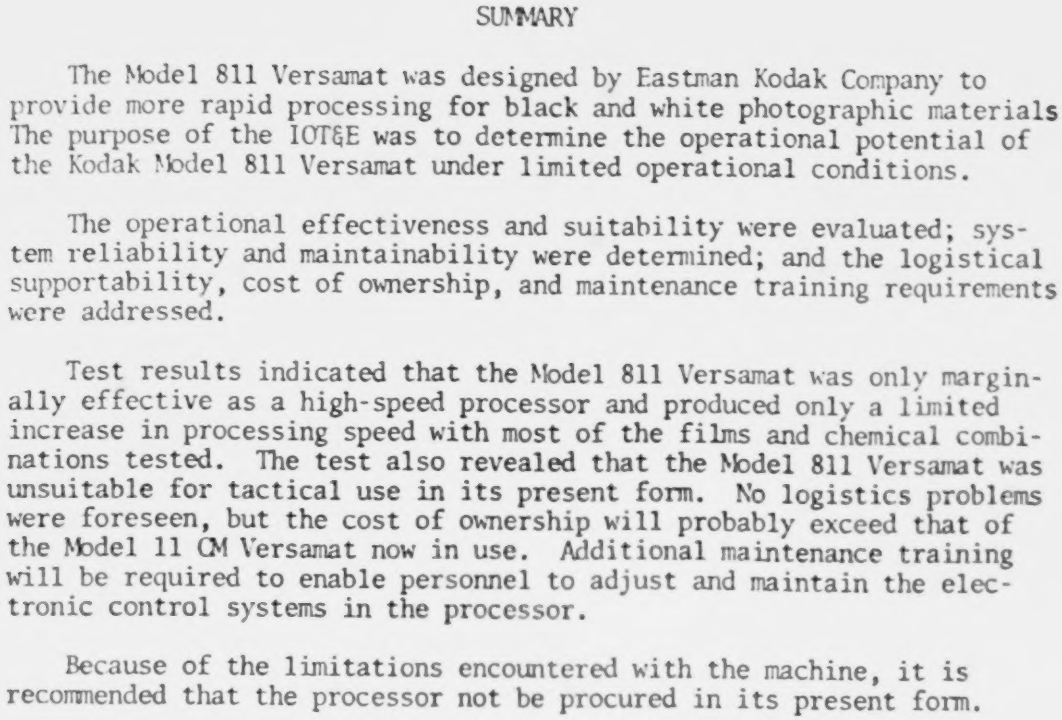
The following personnel were responsible for the conduct of the test:

TAC Project Officer	S. L. HARRIS, Capt, USAF TAC/DRR
Project Manager	R. R. JASPER, 1st Lt, USAF USAFTAWC/TERG
Operations Analyst	Mr. B. STERNER USAFTAWC/OA

The assistance of the following organizations is gratefully acknowledged:

Aeronautical Systems Division (ASD/ENAMC and ASD/RWRE)
Air Force Avionics Laboratory (AFAL/RSP)
62d Tactical Reconnaissance Squadron
25th Special Operations Squadron

Figure 3–19. Foreword page.



SUMMARY

The Model 811 Versamat was designed by Eastman Kodak Company to provide more rapid processing for black and white photographic materials. The purpose of the IOT&E was to determine the operational potential of the Kodak Model 811 Versamat under limited operational conditions.

The operational effectiveness and suitability were evaluated; system reliability and maintainability were determined; and the logistical supportability, cost of ownership, and maintenance training requirements were addressed.

Test results indicated that the Model 811 Versamat was only marginally effective as a high-speed processor and produced only a limited increase in processing speed with most of the films and chemical combinations tested. The test also revealed that the Model 811 Versamat was unsuitable for tactical use in its present form. No logistics problems were foreseen, but the cost of ownership will probably exceed that of the Model 11 CM Versamat now in use. Additional maintenance training will be required to enable personnel to adjust and maintain the electronic control systems in the processor.

Because of the limitations encountered with the machine, it is recommended that the processor not be procured in its present form.

Figure 3–20. Summary page.

(horizontal together with necessary headings, titles, and explanations).

Abbreviations. A page of abbreviations follows the illustrations and tables. This list of abbreviations is used to save space and maintains the occupational language of the Department of Defense or a sponsoring agency. It is used only if the reader can identify the full expression for which it stands.

Introduction. The report begins with a problem that must be solved. It may vary in length, in detail, and in approach. For example, in the report on the Kodak Model 811 Versamat, the author discusses the problem of determining the utility of Model 811 in processing common tactical aerial reconnaissance film in a variety of chemicals.

Purpose. The purpose of this report in the above example was to evaluate the Model 811 and the specific objectives set up to attain these objectives.

Method of accomplishment. Method of accomplishment discusses the environment that was set up to conduct this test and the support provided. Also, it discusses how the Model 811 Versamat was evaluated.

Results and discussion. Some of the questions answered here could be the operational suitability of the Model 811 Versamat. In the test environment, did the Model 811 Versamat fulfill the operational requirement for a high-speed processor? Did the Model 811 Versamat offer some increase in film processing speeds? Did the films used in the model 811 Versamat withstand the higher processing temperatures? If the Model 811 Versamat is adopted for tactical use, will it have a great impact on present concepts or doctrines?

Conclusions. The writer determines what generalizations are established in the body of the report. The writer places these generalizations in the conclusion. The conclusion represents a distillation of the material conveyed in the body of the report. Thus, in our example, we read that the Model 811 Versamat as tested is only marginally effective or in its present form, it is not operationally suited for tactical use, etc. In the report, the generalizations are arranged in a reasonable order and give the reader a "running" account or a thoroughly logical analysis of the sense of the report.

Recommendations. The recommendations represent the considered judgment of the experts. In this case, the writer recommends that the Model 811 Versamat as tested should not be considered for procurement.

Summary. The introductory summary is a condensed version of the report from which and for which it is made. It

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3. Method of Accomplishment 2
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C - Data and Analysis C-1

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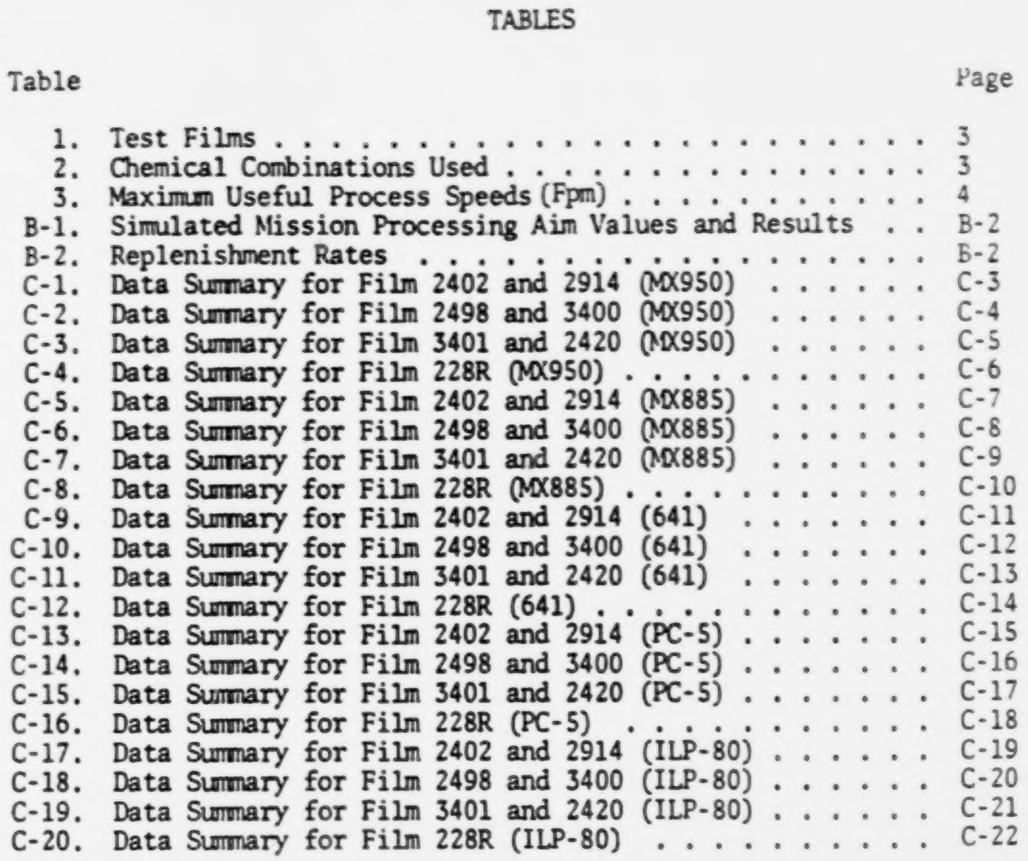

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Figure 3–23. Tables.

repeats the substance of the investigation and actually reproduces the main points found in the investigation.

The procedure for constructing the summary is to reread the report. The writer scans and writes down significant points that appear in the report and the result is a condensed version. The summary is placed on the pages immediately following the foreword.

Exercises (727):

1. What does a test report cover?

2. What is the physical makeup of a test report?

3. Where does the reader get the first impression of the content of the report?

4. Where does the reader see the relationship of the topics that are treated in the report?

ABBREVIATIONS

AFSC	Air Force Specialty Code
ASD	Aeronautical Systems Division
B+F	base plus fog density
D-Log E	density versus logarithm of exposure curve
DT&E	developmental test and evaluation
E	exposure (meter-candle-seconds)
fpm	feet per minute
IOT&E	initial operational test and evaluation
ml/min	milliliters per minute
MTBF	mean time between failures
MTTR	mean time to repair
PC	printed circuit
pH	negative logarithm of the hydrogen ion concentration
TIPI II	tactical information processing and interpretation complex, image interpretation segment
TIPI IP	tactical information processing and interpretation complex, image processing segment
TO	technical order

Figure 3–24. Abbreviations.

5. What is the purpose of using abbreviations?

6. How does a report usually begin?

7. What is the purpose of a report?

8. What does the conclusion in a report represent?

9. What do the recommendations in a report represent?

10. What does the summary in a report represent?

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Answers for Exercises

CHAPTER 1

Reference:

663 – 1. The effects of variables are directly related to the expected image quality. Variations that result in improved image quality can be perpetuated, while the variables that result in reduced image can be eliminated.

663 – 2. Graininess is a subjective visual impression of the silver image and is not directly measurable.

663 – 3. Granularity is an objective evaluation of the silver image and is directly measurable.

663 – 4. Granularity.

664 – 1. The usual way of determining resolving power is to photograph a test object consisting of groups of lines that have a graded (square wave) frequency. The reproduction is viewed under a low-power magnification. The most closely spaced lines that can be distinguished as still being separated establishes the resolving power.

664 – 2. The resolving power of a lens is closely associated with emulsion resolving power, because both are part of the entire system and each exerts its own effect.

664 – 3. High magnification would show the individual grains of silver instead of the lines which are forming the grain.

664 – 4. The resolving power value is the maximum attainable, regardless of the density at which it occurs. The optimum density can be at many levels with different emulsions. Consideration should be given to the range of densities encompassed by the negative.

665 – 1. The method suggested by the National Bureau of Standards is actually a test of the resolving power of the lens-camera-film system when used with a film having a resolution capability at least three times greater than the lens.

665 – 2. A chart consisting of two series of three-bar patterns, differing from adjacent groups by approximately 2 and from opposite groups by the $\sqrt[4]{2}$.

665 – 3. The NBS targets are photographed on a fine-grain high-resolution emulsion at a known reduction, and the developed images are examined under a low-power microscope to ascertain the number of distinguishable lines.

665 – 4. The lines per millimeter only when the targets are photographed at a 25 × reduction, and the target is placed at 26 focal lengths in front of the lens.

665 – 5. Change the distance between the lens and test chart or change the target size by photographic means.

665 – 6. At its axis.

666 – 1. A transparency with an emulsion coated on a glass plate, which has a high degree of dimensional stability.

666 – 2. Either by contract printing or by exposing the film in a good camera.

666 – 3. The greatest number of line-pairs of cycles-per-millimeter that a human observer can barely distinguish in the image of a crenelate (square wave) target.

666 – 4. The resolving power cannot be independent of the optical system that produced the latent image. The resolving power of the photographic material is actually the resolving power of the lens-film system, and the values cannot be separated accurately.

667 – 1. Exposure level; target contrast rates; target shape, if the images are evaluated by the human observer; photographic development, if film is used; and image viewing methods.

667 – 2. The measured value of resolving power.

668 – 1. Expose a piece of sensitized material, using a knife-edged opaque object to hold back exposure from one portion of the material.

668 – 2. Diffraction, reflection, refraction, and diffusion.

668 – 3. Acutance is an objective measure of the ability of a photographic material to show a sharp line of demarcation between contiguous areas receiving low and high exposure.

668 – 4. If the system produces high acutance values in the laboratory, it is predictable that it will do the same under conditions of actual use.

669 – 1. The size of the bits of information photographed at high altitudes is small beyond imagination. The grain structure becomes important to the intelligence information because grain that exceeds the minimum size attainable may block out information vital to the intelligence community.

669 – 2.
- a. Photographs involving distances from aerospace to ground.
- b. Photographs involving distances from ground to aerospace.
- c. Photographs made for research and development assessment.
- d. Photographs having the extremely fine images needed for engineering, aeromedical, and analytical analyses.

670 – 1. The heterogeneity of the developed photographic material.

670 – 2. Graininess is a subjective impression.

670 – 3. With the human eye as a detecting device.

670 – 4. Comparative ratings are made by viewing two or more different materials side by side at a constant magnification.

670 – 5. The method closely corresponds to the real viewing situations; i.e., the practical photographer is usually interested in the maximum enlargement that can be made from a negative without having graininess become objectionable.

671 – 1. Granularity.

671 – 2. The method of establishing granularity is through the use of the microdensitometer.

671 – 3. The microscopic light fluctuations when the photographic material is scanned by a microdensitometer.

671 – 4. The size of the microdensitometer aperture is very important. The size of the aperture affects density fluctuations and it must be considered in the calculations. Large apertures average the grain size so that the trace is practically a straight line. As the aperture becomes smaller, the density fluctuations become more prominent.

671 – 5. Selwyn granularity.

672 – 1. The instrument scans extremely small areas, measures the image, and records the result as a trace on a roll of chart paper. The measurement shows the density of the scanned image plotted against the distance traveled during the scan.

672 – 2. The small, circular apertures are effective for measuring the density levels of small areas or for assessing the uniformity of an evenly exposed area. The slit aperture is generally used to measure distance between various parts of an image.

673 – 1. The intelligence information on a film can be lost through the dimensional instability of the film, and this results from changes in either the emulsion or its support which alter the exactness of reproduction. The chief factors producing such changes—factors you must therefore control—are changes in temperature and humidity.

673 – 2. You must control the environment, the development, the storage, and delivery of the product of your laboratory.

674 – 1. The apparent reversal which occurs when a photographic emulsion is given a short, high-intensity exposure followed by a long exposure to light of low intensity.

674 – 2. The high-intensity first exposure releases electrons more rapidly than the surface traps can neutralize them. The excessive electrons migrate to the interim of the silver halide grain where they form internal latent images or subimage nuclei. These nuclei become electron traps competing with those on the surface for the electrons released during the second long exposure of low intensity. The second exposure produces a greater developable density in the areas not affected by the first exposure.

675 – 1. A reversal effect that occurs when the film is exposed, first, to X-rays and, second, to light.

675 – 2. The Villiard effect was found to depend on temperature. Lowering the temperature for both exposures causes the effect to disappear. Also, it will not occur if the emulsion is bathed in a solution of sodium nitrate before exposure to white light.

676 – 1. It is caused by an overdose of any kind of radiation which can, under proper conditions, produce a latent image.

676 – 2. This effect is not the same for all emulsions. Some do not solarize readily, while others exhibit a marked tendency toward solarization.

676 – 3. Solarization is produced by an overdose of any kind of radiation which can, under proper conditions, produce a latent image. This includes light rays of all wavelengths, UV radiation, X-rays, beams of alpha particles, and ions.

676 – 4. If the developer contains no silver halide solvent, solarization occurs quite readily, while the presence of strong solvents, such as sodium thiosulfate, may completely destroy the solarization effect. Developers containing sodium sulfite will permit solarization if development is not prolonged. When developing time is extended, the solvent action of sodium sulfite can reduce solarization to a marked degree.

676 – 5. In the usual silver bromide emulsion, when exposure is excessive, the bromine reacts with the gelatin at the surface causing rebromination. The latent image nucleus engulfed by the bromine will not respond to the action of the developing solution.

676 – 6. On some emulsions, exposures made at high intensities induced a more pronounced degree of solarization than did those at low intensities.

676 – 7. Lowering the temperature tends to completely prevent the occurrence of solarization.

677 – 1. The photographic effect produced in an emulsion by exposure to blue light may be cancelled if the emulsion is subsequently exposed to red light before development.

677 – 2. Abney exposed the emulsions to light, then treated them with oxidizing agents, and reexposed the emulsion to the electromagnetic spectrum. Abney found the image destroyed from the beginning of the red portion and extending into the infrared. He concluded that oxidation was accelerated by the red light.

677 – 3. One is due to a process of oxidation caused by light absorption of the desensitizing dye, and the other is a reversal effect brought about by the direct action of light upon the latent-image nuclei.

678 – 1. If a film is normally exposed, developed, washed and not fixed, and is given a uniform exposure and developed again, a reversal of the original image will occur.

678 – 2. One explanation is that the negative image produces a screening effect in the subsequent exposure of the silver halide present in the emulsion. The second development produces a positive image. Another explanation is that the effect is due in part to desensitization by metallic silver produced during development of the negative image and to printing of the negative image onto the remaining silver halides.

679 – 1. When a collodion plate is given an excessive exposure and then bathed in nitric acid, washed, reexposed to diffused white light, and developed, a positive image is obtained.

679 – 2. Luppo-Cramer used silver bromide gelatin plates bathed in chromic acid or ammonium persulfate.

679 – 3. The oxidizing solutions remove only part of the photolytic silver produced by the initial exposure, and the rest is present as an absorption complex with silver bromide. This absorption complex resists the attack by chromic acid and is less sensitive to light or less reactive to the developer than the original silver bromide.

680 – 1. A special emulsion, exposed in the dry state, forms a latent image in the interior of the grains. When developed with an internal developer, high density and contrast result. It is then treated to form surface images by subsequent exposure and development. The reversal depends on the sensitivity of the first exposed grains being lowered by the formation of the internal latent-image nuclei.

680 – 2. The work of Arens and Eggert, in 1944, using an emulsion which, when given normal exposure and development, produced a maximum density of just 0.5. However, when exposed while immersed in developer, this emulsion gave a density of 2.0 or higher, though the areas which had gotten the initial exposure in the dry state responded to a much less degree to the second exposure, so continued development gave a reversal image. The negative image, developed at the same time, had so little density and contrast that it did not interfere with the final positive image, and the final result showed a reversal with a minimum density which, at first, seemed a Sabbattier reversal, though it later proved internally more like the Albert reversal.

681 – 1. Adjacent areas of different densities are usually involved.

681 – 2. Chemical changes produced in the development process. They increase in proportion to the amount of silver developed.

681 – 3. The rate of diffusion is dependent upon the nature of the reaction products, the physical character of the emulsion, and the temperature of the processing solution.

681 – 4. During development, reaction products are formed in the emulsion and diffuse outward into the developer.

681 – 5. By agitating either the film, the solution, or both.

682 – 1. When reaction products hold back the rate of development and are confined within the emulsion, the effects are called retardation.

682 – 2. Border effect; fringe effect.

682 – 3. A microdensitometer.

683 – 1. When a series of exposures are made through holes of various sizes cut into an opaque mask, the developed images will show a higher density through the smaller holes than the images resulting from exposure through the larger openings.

683 – 2. Demonstrations have demonstrated that an aperture of about 0.1 mm produces the maximum density.

684 – 1. The Kostinsky effect occurs when two small images are formed close to each other.

684 – 2. Reaction products.

684 – 3. The Kostinsky effect can be evaluated by photographing two point sources of light placed a known distance apart. The distance between the measured separation and the calculated separation give an indication of the effect.

685 – 1. Bromide streaks are formed near the surface of the emulsion when the reaction products form an area of high-density flow outward and retard the development in the adjacent area. Developer streaks, on the other hand, are caused by the passage of unused developing agents from low-density areas to areas of greater density, increasing the rate of development in those areas.
685 – 2. Proper agitation will do much toward preventing the occurrence of bromide and developer streaks.

686 – 1. If an emulsion is given a uniform exposure and allowed to be stagnant in a horizontal position in the developer, mottle may result.
686 – 2. The condition can be avoided if proper agitation is given during processing.

687 – 1. Directional effects are a special condition of bromide and developer streaks.
687 – 2. In machine processing.
687 – 3. Yes. When comparing two sensitometric exposures, each rotated 180° from the other, the strip leading with the end having maximum exposure gave off more bromide and had a greater restraining effect on the minimum exposure density.

688 – 1. The release of semiquinone acts as an accelerator. The formaldehyde acts as a sulfite buffer which maintains an optimum sulfite concentration. The sulfite eventually unites with the semiquinone to form a stable, inert complex.
688 – 2. The turbulence created when the developer surges through the film perforations causes an increased development in adjacent areas.

689 – 1. Increases the speed and gamma of the film.
689 – 2. To the localized fogging action of the reaction products in the vicinity of exposed and normally developed grains.
689 – 3. The hydrazine combines with the semiquinones to form the fogging agent.
689 – 4. The life of the fogging agent is short-lived.
689 – 5. Infectious development.
689 – 6. The effect obtained from developers whose reaction products are accelerating agents disappears as development time is increased, whereas the effect produced by developers whose reaction products are fogging agents increase with the time of development.
689 – 7. The transfer of developability may be produced by the extruded silver filaments of the developing grain coming into contact with the surrounding unexposed grains.

690 – 1. A developed sample in an aqueous solution will absorb water and swell to a degree governed by the tanning of the gelatin.
690 – 2. As a high-density area dries more quickly than a low density area, it tans readily and shrinks on drying, pulling the still moist and flexible low-density areas with it.

691 – 1. It passes through a series of solutions which vary greatly in acidity and alkalinity.
691 – 2. It induces swelling of the emulsion.
691 – 3. Since the fixing bath is usually acid, there is a great strain in the gelatin structure as the emulsion contracts rapidly.
691 – 4. The use of wash water much warmer than the processing baths.
691 – 5. There is an actual migration of silver particles owing to tension similar to that occurring during the drying of moisture spots; the silver particles aggregate in the drying edge and move outward from the center.

692 – 1. The size of the receptors (rods and cones) on the retina; the distance between the object and the nodal point of the eye; and the angle that the object subtends at the optical center or nodal point of the eye.
692 – 2. Move it as near to the eye as possible.
692 – 3. Make a series of grids consisting of alternate opaque and transparent lines varying in regular increments. Each grid is viewed by transmitted light of about 10 foot-candles at a distance of 10 inches from the eye. The grid whose lines are just visible is taken as the measure of the minimum detectable object size.

693 – 1. The simple microscope is a short-focus lens used as a magnifier or reading glass.
693 – 2. Hand magnifiers, jeweler's loupes, linen testers, and simple comparators.
693 – 3. By remagnifying a magnified aerial image.
693 – 4. The objective lens looks at the object and produces an enlarged aerial image within the tube of the instrument.
693 – 5. It is enlarged and virtual.

694 – 1. The product of the power of the ocular and the objective.
694 – 2. The magnification is a product of the two, and the combination will operate at 470X.

695 – 1. The design of the objective.
695 – 2. The resolving power is inversely proportional to the numerical aperture of the objective.
695 – 3. By decreasing the wavelength λ, increasing the angle U, and increasing the index of refraction, n.

696 – 1. Achromats, fluorites, and apochromats.
696 – 2. The apochromat.

697 – 1. The Huygenian, the hyperplane, and the compensating eyepieces.
697 – 2. Eyepieces used for special applications on the microscope include the Ramsden, the widefield, and the ultraplane.

698 – 1. A light source, a mirror, and a condenser.
698 – 2. Without illumination, the specimen cannot be seen, and the performance of even the best microscope will be unsatisfactory if the illuminating system is inadequate or incorrectly used.

699 – 1. A substage iris, a condenser, and a mirror to direct the light from the illuminator.
699 – 2. By removing the eyepiece and peering down into the tube at the back lens of the objective, you can open and close the iris and observe the image near the back lens of the objective.
699 – 3. Full aperture illumination is obtained when the image of the iris just fills the full aperture of the objective.

700 – 1. To direct a light beam of the desired size onto the specimen slide.
700 – 2. The Abbe condenser, the variable focus condenser, and the achromatic condenser.
700 – 3. The Abbe condenser has excellent light gathering capabilities.
700 – 4. Since the achromatic condenser is corrected for both chromatic and spherical aberrations, it is used extensively for photomicroscopy in color.

701 – 1. Illuminator.
701 – 2. To supply illumination to the specimen.

CHAPTER 2

702 – 1. To make precisely controlled photographic exposures to produce step tablets or continuous wedges (gray scales).
702 – 2. To measure the densities of these items and of the actual film itself.
702 – 3. To detect any significant change in the response of the measuring device.
702 – 4. Significant changes in exposure produced by the sensitometer over the useful life of its light source.
702 – 5. Whether or not the instrument measures density within prescribed specifications.

703 – 1. Only when the sensitometers are of the same make and model.
703 – 2. At least 1 inch wide and 5 inches long.
703 – 3. Affix emulsion side up, to a roll of leader material. All samples must be oriented parallel to the direction of travel with the area of least exposure receiving development first. The strips should not be grouped but should be distributed randomly.

703 – 4. Three.
703 – 5. When the inherent variability of the test is approximately 0.02 Log E.

704 – 1. Certification of production equipment.
704 – 2. A series of comprehensive performance tests that are used to assure that each piece of equipment is in proper working order.
704 – 3. The level of excellence required in the photographic output.
704 – 4. The following equipment is usually found in a ~~photoprocessing~~ Imagery Production laboratory: processors, printers, titlers, film cleaners and waxers, viewing devices, and other product-handling and quality-measuring devices.

705 – 1. To detect and correct any mechanical and/or sensitometric conditions that could lead to the degradation of the information content of the image being processed.
705 – 2. To insure that the processor or the processing system does not cause physical degradation of the film.
705 – 3. a. Physical defects such as abrasions, scratches, etc., caused by mechanical portions of the processor.
b. Processing defects; i.e., water spots, developer sprayback, mottle, chemical stain, etc.

706 – 1. Processor startup procedures; physical quality of the processed material; freedom from processing defects; uniformity of processing; and attainment of desired sensitometric characteristics.
706 – 2. The film type and width and the sensitometric specifications.

707 – 1. Because the sensitometric strips must be stored at 0°F until softly after use.
707 – 2. This requirement is based upon the fact that different emulsions will exhibit different degrees of susceptibility to physical abrasions and tracking problems.
707 – 3. The type of processor being used and the previous stability history of the processor.
707 – 4. The piggyback fashion minimizes the number of splices and allows the strips to be easily removed at the end of the processor.
707 – 5. Because the process chemistry is altered by the replenishment system continuing to function when no material is being developed.

708 – 1. To insure that the processor is operated in accordance with the recommendation set forth by the manufacturers and to outline the tasks which must be performed to bring the processor to an operational state.
708 – 2. An inspection of the various components to detect conditions that would result in the processor failing to certify under the Quality Assurance (QA) Test.

709 – 1. To determine if the processor is capable of processing mission material without imparting physical or processing defects that can result in the loss of intelligence information.
709 – 2. Different bases, base thickness, and emulsions react differently to the various out-of-standard conditions.
709 – 3. Many defects that are located on the base side of the material are difficult to detect when viewing the emulsion side; therefore, both sides of the material must be examined.
709 – 4. Abrasions caused by roller sticking due to crystallized chemicals in the roller bearings, tracking problems resulting in deckled edges, occurring until all of the film that was used to load the processor clears the machine; and scratches caused by chemicals crystallized on the surface of the rollers.
709 – 5. Run 100 feet of simulated product before processing the test material.

710 – 1. To determine if the processing is uniform across the width of the film.
710 – 2. The major difference between the two test procedures is that of the orientation of the test sample during processing.
710 – 3. The Printing Aperture Illuminance Uniformity Test sample is obtained from a 90° turnaround portion, while the Processing Uniformity Test sample is taken from either a normal section or a 180° turnaround section.
710 – 4. Through the use of a recording densitometer to obtain a trace of the density variation across the width of the flashed film sample.
710 – 5. To determine if the processing uniformity achieved is acceptable.
710 – 6. A 90° turnaround splice.

711 – 1. A quantitative comparison between the photographic effect currently produced by the processor and the adapted standards that are embodied in the process aim curve.
711 – 2. That the desired photographic effect is being produced before the mission material is introduced to the processor.
711 – 3. The process control phase.
711 – 4. Several sensitometric strips separated by several hundred feet of simulated product.
711 – 5. Run one or two additional sensitometric strips with the simulated product, after accepting the first certified sensitometric strip.
711 – 6. The use of a starter solution or the addition of appropriate amount of bromide, iodide, and acetic acid can be used to artifically age the solution.
711 – 7. Erroneous certifications may result from a nonrepresentative strip or an evaluation error.
711 – 8. A rational subgroup consisting of two or more adjacently processed strips should be used. The results of the strips should be averaged and then compared to the control limits and plotted on a control chart.
711 – 9. The use of rational subgroups decreases the variability or error associated with the evaluation technique.

712 – 1. Viewer's motorized film transports, ultrasonic film cleaners, automatic film titlers, waxers, and film splicers.
712 – 2. Improper use, mechanical malfunctions, etc., of the support equipment can have a serious impact on the physical condition of the film.
712 – 3. It is a performance test conducted prior to a mission to assure that equipment is in proper working order and does not abuse the film in any way.
712 – 4. Performance Certification Test (e.g., machine speed, temperature); Physical Abrasion Test (e.g., scratches on emulsion); Mechanical Defects Test (e.g., misalignment of tracking system and burrs on rollers that can tear or mutilate the film); and Contaminant Inspection (e.g., removal of dust, oil, grease, and other contaminants present on machines that could be transferred to the film).

713 – 1. To determine if the instrument's density measurements are within tolerance.
713 – 2. Reading at least three of the steps contained on a standard step tablet and then comparing these readings to the step tablet's calibrated densities.
713 – 3. The densitometer should be sent to the maintenance section for recalibration.

714 – 1. To determine if the instruments are within tolerance.
714 – 2. The temperature gauge and the thermostat control switch.
714 – 3. A standard laboratory thermometer of known accuracy that reads in degrees Fahrenheit.
714 – 4. Check the incoming water supply to be sure that it is adequate.
714 – 5. The developer circulation system should be checked.
714 – 6. That the thermostat is not operating properly.

715 – 1. The dryer air temperature gauge and the dryer air thermostat control switch.
715 – 2. A thermometer.
715 – 3. Adjustment of the air temperature gauge is in order.
715 – 4. The dryer thermometer.
715 – 5. Erratic readings on the thermometer.

716 – 1. On the mixing valve.
716 – 2. Loosen the retaining nut and slide the unit up and out.

591

716 – 3. A standard thermometer.

717 – 1. Daily.
717 – 2. Stopwatch or sweep second hand on a wristwatch.
717 – 3. The speed calibration chart.

718 – 1. The amount of solution passing through the flowmeters is measured, and a calibration curve is plotted on a graph.
718 – 2. Operate the replenisher pump and collect the solution discharging from feedline in a graduated cylinder.
718 – 3. A stopwatch or a wristwatch with a sweep second hand.
718 – 4. Clean the tubes.

719 – 1. The titration and spectrophotometric method.
719 – 2. The weighing of two portions of sodium chloride, dissolving the *larger* in the tank to be calibrated and the *smaller* in a volumetric flask.
719 – 3. Silver nitrate.
719 – 4. Potassium chromate.
719 – 5. Sodium chloride.
719 – 6. Metanil yellow.
719 – 7. The absorbance of the reference solution at different wavelengths.

CHAPTER 3

720 – 1. Speed and gamma.
720 – 2. The film is specifically designed to have high gamma in order to counteract the reduction in contrast caused by atmospheric haze.
720 – 3. The criterion of availability.
720 – 4. This developer at 90°F has poor stability and does not give satisfactory development.
720 – 5. The developer can be used for low-contrast development of Plus X Aericon film at 90° F.

721 – 1. A 90-second developing time.
721 – 2. Phenidone–Glycin developer is also suitable for use at 68 ° F.
721 – 3. Under these conditions, higher gammas are obtained, and the developer cannot be regarded as a low-contrast developer.
721 – 4. Less than 30 percent loss in film speed and less than 15 percent loss in gamma.
721 – 5. The gamma for the stored material is somewhat higher than for the controlled.
721 – 6. 1 month.
721 – 7. The maximum density.

722 – 1. To make sure that the properties of the developer are due to the combination and not to Glycin or Phenidone alone.

723 – 1. The addition of potassium bromide or the lowering of pH.
723 – 2. Stability to oxidation.
723 – 3. Produced undesirably low maximum densities.
723 – 4. They were found to give lower contrasts and lower maximum densities at 90°F than at 68°F.
723 – 5. The oxidation effects.

724 – 1. Controlled areas, standard clean rooms, and clean work stations.
724 – 2. A controlled area is any workspace, room, shop, or facility requiring cleanliness beyond normal housekeeping. An area in which clean room equipment is repaired or overhauled is an example of a controlled area.
724 – 3. Your installation sets the limits for your controlled areas according to your requirements.
724 – 4. Any room, shop, or facility in which environmental conditions are positively controlled is designated as an AF standard clean room (AFSCR). Rooms used for the preinspection of film, film processing, and printing of duplicate negatives and positives are examples of an AF standard clean room.
724 – 5. The quality of the product being produced.
724 – 6. Any contamination-controlled workspace designed to insure a high degree of cleanliness in the immediate vicinity of a task or an operation.
724 – 7. The requirements for airborne contamination control are higher for AFCWs than for AFSCRs.

725 – 1. The first set is to be met when the environmental control systems are operating but no work is being done, and the second set is to be met when the environmental control systems are operating during production.
725 – 2. The air-conditioning system in an AFSCR must be able to provide a temperature range of 67 to 77°F.
725 – 3. Forty percent relative humidity is the allowable maximum for an AFSCR when no work is being done.
725 – 4. Limit its particles per cubic foot (p/cf) to 20,000 particle or less, 0.4 micron and larger, with not more than 4,000 p/cf, 1.0 micron and larger.
725 – 5. All contaminants that are found in imagery production laboratories. These include dust, lint, vapor, chemicals, bacteria, spores, and gaseous substances.

726 – 1. The flowmeters and temperature gauges.
726 – 2. In heat exchange tanks incorporated in the circulating system of the processor.
726 – 3. A quick-fill capability, as well as a drain-and-flush capability.
726 – 4. The HTA2, HTA3, HTA3C, the HTA3CM, the Dalton film processor, and the Trenton film processor.

727 – 1. An entire investigation.
727 – 2. The format.
727 – 3. The title page.
727 – 4. The table of contents.
727 – 5. To save space and maintain the occupational language of the Department of Defense or the sponsoring agency.
727 – 6. With a problem that must be solved.
727 – 7. To evaluate the problem and the specific objectives set up to attain these objectives.
727 – 8. A distillation of the material conveyed in the body of the report.
727 – 9. The considered judgment of the experts.
727 – 10. A condensed version of the report. It repeats the substance of the investigation and reproduces the main points found in the investigation.

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BEST COPY AVAILABLE

STOP- 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 04B 01

CHEMICAL ANALYSIS AND PROCESS CONTROL

Carefully read the following:
DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (663) Information content of the silver image is largely a function of

   a. acutance.
   b. resolution.
   c. graininess.
   d. granularity.

2. (664) When we attempt to establish the resolving power of an emulsion, what factor do we consider?

   a. Fine detail.
   b. Edge sharpness.
   c. Signal-to-noise ratio.
   d. Frequency modulation transfer.

3. (664) Resolution tests of emulsions are examined with a microscope at a magnification of what power?

   a. 25 to 50.
   b. 50 to 100.
   c. 100 to 200.
   d. 430.

4. (665) The diagonally arranged numbers in the NBS targets indicate the lines per millimeter when the targets are photographed at what reduction?

   a. 5X.
   b. 10X.
   c. 20X.
   d. 25X.

5. (666) Unlike the NBS target, the USAF 1951 test object is a transparency and has what kind of a base?

   a. Glacial.
   b. Polyester.
   c. Plastic.
   d. Glass.

6. (666) The most popular test patterns follow what kind of an arrangement?

   a. Tricolumnar.
   b. Sunburst.
   c. Doughnut.
   d. Block letters.

7. (667) Maximum possibility of recognition of resolution occurs when the contrast ratio between lines and background is above

   a. 1:1.
   b. 10:1.
   c. 100:1.
   d. 1000:1.

8. (668) What object is used to measure acutance to expose a piece of sensitized material?

   a. Binocular.
   b. Microscope.
   c. Test target.
   d. Knife-edge opaque.

9. (668) The adjacent areas of acutance material are scanned with a

   a. microdensitometer.
   b. spectrophotometer.
   c. densitometer.
   d. sensitometer.

10. (668) What two measurements are used to calculate acutance?

    a. Density-distance.
    b. Density-exposure.
    c. Distance-exposure.
    d. Gradient-segments.

11. (670) What detecting device is used to rate graininess?

    a. Eye.
    b. Microscope.
    c. Microdensitometer.
    d. Spectrophotometer.

12. (671) A method of establishing granularity is through the use of the

a. densitometer. c. microdensitometer.
b. sensitometer. d. spectrophotometer.

13. (671) A granularity computation where the microdensitometer aperture size is taken into consideration is known as what kind of granularity?

a. Ross. c. Selwyn.
b. Sabattier. d. Eberhard.

14. (672) In microdensitometry, what does small circular aperture measure?

a. Grain. c. Distance.
b. Acutance. d. Density level.

15. (672) In Microdensitometry, what patterns are used to provide the information for modulation-transfer-function calculations?

a. Embrace. c. Circle.
b. Sine-wave. d. Crenel.

16. (673) Which of the following does dimensional stability of a film rely heavily upon?

a. Type of developer used. c. The emulsion on base material.
b. Controlling the reproduction. d. Your laboratory standard.

17. (674) In the Clayden effect, what does the first high-intensity exposure do to the emulsion?

a. Sensitize. c. Neutralize.
b. Desensitize. d. Retards electron activity.

18. (676) When silver halides receive an exposure greater than necessary to produce maximum density, the effect is called

a. rehalogenation. c. rebromination.
b. solarization. d. neutralization.

19. (676) Emulsions exposed at low temperatures tend to completely prevent the occurrence of

a. radiation. c. rebromination.
b. solarization. d. rehalogenation.

20. (677) A photographic effect produced in an emulsion by exposure to blue light and then cancelled subsequently by red light is what kind of an effect?

a. Villiard. c. Clayden.
b. Herschel. d. Sabbattier.

21. (678) A normally exposed, developed and washed film (not fixed) when given a second exposure and developed again produces a reversal. What is this effect called?

a. Clayden. c. Sabbattier.
b. Villiard. d. Herschel.

22. (679) A wet collodion plate when given an excessive exposure, bathed in nitric acid, washed, reexposed to diffused light, and then developed to a positive image is called what kind of an effect?

a. Clayden. c. Sabbattier.
b. Herschel. d. Albert.

23. (680) In developing an image the Sabbattier effect gives an unsatisfactory reversal image because of the

a. low maximum density.
b. nonsolvent developer.
c. desensitization.
d. fog level.

24. (681) Adjacency processing effects are generally thought to be caused by what changes produced in the developer?

a. Chemical.
b. Physical.
c. Photolytic.
d. Turbid.

25. (682) The border and fringe effects are frequently referred to together as what effects?

a. Gelatin.
b. Eberhard.
c. Kostinsky.
d. Edge.

26. (682) The essential condition for obtaining the border and fringe effects is a relatively sharp boundary between two areas having a large difference in

a. contrast.
b. density.
c. exposure.
d. development.

27. (673) Experiments with the Eberhard effect have demonstrated that the density reaches a maximum when the diameter is about what size?

a. 0.01 mm.
b. 0.1 mm.
c. 1.0 mm.
d. 10 mm.

28. (685) What streaks show areas slightly more dense than immediately adjacent areas and stream out from low-density areas on the negative?

a. Developer.
b. Bromide.
c. Directional.
d. Mottle.

29. (685) Evidence presented shows that bromide and developer streaks result from what condition produced in the developing solution?

a. Temperature.
b. Convection currents.
c. Specific gravity.
d. Agitation.

30. (686) When a uniformly exposed photographic material is developed horizontally in a solution not agitated, the resulting development produces a variation in density called

a. performation effect.
b. sprocket hole modulation.
c. development mottle.
d. infectious development.

31. (687) Where are directional effects most likely to occur?

a. Mix tank.
b. Film titler.
c. Machine processing.
d. Micro-image scanner.

32. (688) In developer containing formaldehyde-hydroquinone, what reaction product accelerates development?

a. Hydrobromic acid.
b. Potassium bromide.
c. Semiquinone.
d. Hydrazine.

33. (689) What chemical usually combines with the semiquinones to form a fogging agent?

a. Hydrogen peroxide.
b. Hydrazine.
c. Sodium sulfite.
d. Sodium hydroxide.

34. (690) Because the amount of tanning products present in a gelatin is proportional to the quantity of silver produced, it follows that this swelling is a function of image

a. density.
b. contrast.
c. exposure.
d. development.

35. (691) The most common cause of reticulation is the use of

a. alkali.
b. acid.
c. cold water.
d. warm water.

36. (691) What does the alkalinity of a developing solution induce in the photographic emulsion?

a. Hardening.
b. Swelling.
c. Tension.
d. Turbidity.

37. (692) Where no functional defects exist, the size of an object which can be detected by the unaided eye is dependent upon

a. the size of the receptors on the retina.
b. the distance between the object and the nodal point of the eye.
c. the angle that the object subtends at the optical cent or nodal point of the eye.
d. all of the above.

38. (692) The nearest point that an object can be seen distinctly by the normal eye is about how many inches?

a. 20.
b. 15.
c. 10.
d. 5.

39. (693) In the compound microscope, the image formed by the eyepiece is enlarged and

a. aerial.
b. inverted.
c. real.
d. virtual.

40. (694) Magnification is the product of the power of the ocular and the

a. subjective.
b. objective.
c. eye.
d. condenser.

41. (694) The magnification of a microscope is limited mainly by what characteristic of the optical equipment?

a. Refraction.
b. Dispersion.
c. Resolving power.
d. Diffraction.

42. (695) How is the resolving power of a microscope related to the numerical aperture of the objective?

a. Directly proportional.
b. Inversely proportional.
c. Logarithmically.
d. Algebraically.

43. (696) Which of the following is *not* a major type of microscopic objective?

a. Achromat.
b. Fluorite.
c. Apochromat.
d. Meniscus.

44. (697) The most common eyepiece for the microscope is the

a. Ramsden.
b. Hyperplane.
c. Huygenian.
d. Widefield.

45. (697) In the Huygenian lens, what physical characteristic of light causes the red and blue rays to become parallel?

a. Reflection.
b. Dispersion.
c. Diffraction.
d. Refraction.

46. (697) What eyepiece is used extensively when the microscope is used to make measurements?

a. Widefield.
b. Huygenian.
c. Ramsden.
d. Ultraplane.

47. (698) An illumination system usually includes

a. a light source.
b. a mirror.
c. a condenser.
d. all of the above.

48. (699) What controls the illumination of the aperture of the microscope?

a. Iris diaphragm.
b. Condenser system.
c. A mirror.
d. Fine adjustment.

49. (700) A substage condenser that has excellent light gathering capabilities is the

a. Achromatic.
b. Apochromatic.
c. Abbe.
d. Variable.

50. (702) An instrument that makes precise controlled photographic exposures is the

a. densitometer.
b. sensitometer.
c. printer.
d. titler.

51. (703) The first task to perform when correlating a sensitometer is to certify the

a. sensitometer.
b. processor.
c. densitometer.
d. chemistry.

52. (704) The certification procedure of printer performance is based upon what concepts?

a. Tone reproduction.
b. Tone control.
c. Subjective evaluation.
d. Objective evaluation.

53. (705) What kind of certification must be performed with the processors to detect mechanical conditions that may lead to image degradation?

a. Physical.
b. Processing.
c. Postmission.
d. Premission.

54. (705) What test insures that the processor does not cause physical degradation to the film?

a. Quality assurance.
b. Start up.
c. Sensitometric.
d. Illuminance.

55. (706) Which of the following statements accurately represents the mission requirements for the certification of film processors?

a. Film type.
b. Film width.
c. Sensitometric specifications.
d. All of the above.

56. (706) To determine the chemical and mechanical requirements, what curve is consulted for the desired sensitometric response?

a. Process aim.
b. H & D.
c. D Log H.
d. Characteristic.

57. (706) Which of the following items is *not* a physical defect of the emulsion?

a. Scratches.
b. Abrasions.
c. Chemical stain.
d. Dimples.

58. (706) When the processing solutions are continuously recirculated and maintained at the desired temperature, the certification of the processor for mission use is valid for how many hours?

a. One hour.
b. Two hours.
c. Four hours.
d. Eight hours.

59. (707) Using large segments of leader material in a certification roll tends to increase the concentration of developing agents while decreasing what other process chemistry?

a. Bromide.
b. Sulfite.
c. Carbonate.
d. Hydroquinone.

60. (707) Flashed materials are stored at what normal room conditions?

a. Less than 60% RH and less than 75° F.
b. Less than 75% RH and less than 60° F.
c. More than 60% RH and less than 75° F.
d. More than 75% RH and less than 60° F.

61. (707) What method permits the sensitometric strip to be secured to the leader material with tape?

a. Cross-over.
b. Spliced.
c. Rollback.
d. Piggyback.

62. (708) Most of the information included in the processor startup procedure is usually contained in what literature?

a. Techinical orders.
b. Operating manuals.
c. Civilian publications.
d. Air Force regulations.

63. (709) What defects frequently occur when a processor is used for the first time after an extended shutdown and then does not appear in the processing of subsequent film?

a. Long-term-self perpetuating.
b. Long-term-self eliminating.
c. Short-term-self perpetuating.
d. Short-term-self eliminating.

64. (709) To insure that the Processor Quality Assurance Test is not affected by short-term defects, how many feet of simulated product should be run before processing the test material?

a. 25.
b. 50.
c. 100.
d. 200.

65. (710) The easiest method of evaluating the sample from the Processing Uniformity Test is through the use of what instrument?

a. Conventional densitometer.
b. Recording densitometer.
c. Microdensitiometer.
d. Photometer.

66. (710) Tentative sigma control limits for the Processing Uniformity Test are determined after how man tests?

a. 5 to 10.
b. 10 to 15.
c. 15 to 20.
d. 20 to 25.

67. (711) When aging the developer for an original negative processor, it is a good policy to run how many additional sensitometric strips with the simulated product to check stabilization?

a. One or two.
b. Three or four.
c. Five or six.
d. Seven or eight.

68. (712) What is the test procedure recommended for machine speed?

a. Performance Certification.
b. Physical Abrasion.
c. Mechanical Defects.
d. Contaminant Inspection.

69. (712) What test procedure is recommended for misalignment of tracking system and burrs on rollers than can tear or mutilate the film?

a. Physical Abrasion.
b. Contaminant Inspection.
c. Mechanical Defects.
d. Performance Certification.

70. (713) To determine if an instrument's density measurements are within tolerance is the purpose of what certification?

a. Sensitometer.
b. Densitometer.
c. Step tablet.
d. Continuous wedge.

71. (713) When certifying a laboratory densitometer, an evaluation of the linearity of its response can be made by monitoring how many steps of the step tablet?

a. 1.
b. 2.
c. 3.
d. 4.

72. (714) The purpose of the temperature device certification is to determine

a. if the instruments are within tolerance.
b. if the instruments can sense the developer temperature.
c. if the processor is operating normally.
d. if an accurate developer temperature can be maintained.

73. (714) What is the recommended pressure for the incoming water supply in a developer tank?

a. 25 psi.
b. 45 psi.
c. 60 psi.
d. 75 psi.

74. (715) What instrument is used to check the reliability of the dryer air temperature gauge?

a. Hydrometer.
b. Barometer.
c. Psychrometer.
d. Thermometer.

75. (716) The readings of the water temperature gauge and the standard thermometer should be comparable to within how many degrees Fahrenheit?

a. 0.5.
b. 1.0
c. 1.5.
d. 2.0.

76. (717) How often should the calibration of the speed indicator on the Versamat 11-CM processor be checked?

a. Daily.
b. Weekly.
c. Frequently.
d. Infrequently.

77. (718) To provide accurate control of the solution replenishment rates of a Versamat 11-CM processor, what must be done with the amount of solution passing through the flowmeters?

a. Calibrated.
b. Measured.
c. Checked.
d. Collected.

78. (719) In the titration method, solutions taken from the mix tank and volumetric flask are titrated with

a. silver nitrate.
b. potassium chromate.
c. sodium chloride.
d. metanil yellow.

79. (719) When metanil yellow is dissolved in the mix tank and volumetric flask, the solutions are measured by what method?

a. Stoichiometric.
b. Spectrophotometric.
c. Volumetric.
d. Cerimetric.

80. (720) What is Kodak Plus X Aerecon film specifically designed to have?

a. Low maximum gamma.
b. High maximum gamma.
c. Low definition for high altitude.
d. High definition for high altitude.

81. (720) The Phenidone-Glycin developer was formulated to process aerial film at

a. 68° F.
b. 75° F.
c. 90° F.
d. 120° F.

82. (721) The packaged dry powder of the Phenidone-Glycin developer can be stored at 120° F for how many days without harmful effects?

a. 7.
b. 14.
c. 21.
d. 28.

83. (721) The Phenidone-Glycin developer solution can be stored in stoppered containers at a temperature not over 100° F for what period of time?

a. 15 days.
b. 1 month.
c. 45 days.
d. 2 months.

84. (722) The Phenidone-Glycin combination gives better balance of speed and gamma for what type of development?

a. High-contrast.
b. Low-contrast.
c. Weak.
d. Concentrated.

85. (723) What phenomenon is responsible for the low-contrast development obtained at 90° F with the Phenidone-Glycin combination?

a. Oxidation.
b. Reduction.
c. Addition.
d. Subtraction.

86. (724) In the Air Force, all of the following are designated as clean rooms *except*

a. controlled areas.
b. standard clean rooms.
c. base photo labs.
d. clean work stations.

87. (724) Any facility requiring cleanliness beyond normal housekeeping is classified as a

a. standard clean room.
b. controlled area.
c. clean work station.
d. photoprocessing laboratory.

88. (725) The air-conditioning system in an AFSCR must be able to provide a temperature range of

a. 67° to 77° F.
b. 70° to 80° F.
c. 75° to 85° F..
d. 90° to 100° F.

89. (725) The air-handling system should be able to change the air in an AFSCR approximately how many times per hour?

a. 20.
b. 30.
c. 40.
d. 50.

90. (726) In the operation of a control panel, what instruments show the status of the various machines in operation?

a. Tachometers and speed indicators.
b. Heat and ion exchangers.
c. Pressure gauges and IR converters.
d. Flowmeters and temperature gauges.

91. (726) To prevent foreign matter from accidentally falling into the mixing tanks, all storage tanks should be equipped with

a. covers.
b. baffles.
c. filters.
d. deflectors.

92. (727) The physical makeup of a test report is called the

a. cover.
b. format.
c. title.
d. illustrations.

93. (727) Headings and subheadings that show the relationship of the topics that are treated within the report are found in the

a. table of contents.
b. results and discussion.
c. summary
d. conclusion.

94. (727) The area that represents a distillation of material conveyed in the body of the report is called the

a. summary.
b. recommendation.
c. discussion.
d. conclusion.

95. (727) The area that repeats the substance of the investigation and reproduces the main points is called the

a. conclusion.
b. summary.
c. discussion.
d. forward.

END OF EXERCISE

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5	Correct SSAN. *(List incorrect SSAN here.)* *(Correct SSAN should be shown in Section I.)*
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9	Send course materials. *(Specify in "Remarks")* [ ] Not received [ ] Lost [ ] Damaged
10	Course exam not yet received. Final VRE submitted for grading on ____________ (date).
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IMAGERY PRODUCTION SPECIALIST

(AFSC 23350)

Volume 5

Sensitometric Control for Black-and-White and Color Processes

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Preface

NOW THAT you have completed Volume 4, you will continue with Volume 5 of this CDC. This volume presents additional information of tasks essential to the operation of an imagery production facility. The purpose of this volume is to upgrade your knowledge needed to advance you up the career ladder.

This volume discusses sensitometric procedures that are performed in order to obtain all possible information from each reconnaissance/mapping mission. Building upon your previous training, this volume will help you understand how sensitometric exposures determine a particular film's speed and its proper exposure. By measuring densities in a mission negative and comparing them to sensitometric exposures, you can establish controls over processing time, temperature, and solutions. Also discussed are the effects of development on density, gamma, and contrast and the means by which each of these is measured and represented in order to establish sensitometric and tone reproduction controls. Standards established by color sensitometry are discussed in setting up controls over the processing system.

The advent of color photography, for both terrestrial and aerospace purposes, has introduced a host of new methods, instruments, and terms into the field of sensitometry. Color sensitometry has grown to the point that it is considered as a separate division in the overall field of sensitometry. The standards established by color sensitometry are useful in setting up controls over aerial photography or over the processing system. Exposure and choice of color materials are only half the battle, since processing and printing are involved. It is for the latter reason that the imagery production specialist must understand color sensitometry. Otherwise, he or she will not be able to evaluate the effectiveness of the process being used.

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To get an *immediate response* to your questions concerning subject matter in this course, call the author at AV 926-4142 between 0730 and 1630 (MT), Monday through Friday. Otherwise, write the author at 3448 SCH SQ/TTMZS (ATC), Lowry AFB CO 80230, to point out technical errors you find in the text, volume review exercises, or course examination. Sending subject matter questions to ECI slows response time.

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This volume is valued at 39 hours (13 points).

Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes the examinee should check the Index of ECI Study Reference Material to determine the correct references to study.

Acknowledgement

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CHAPTER 1

Sensitometry—Densitometry

IN MANY RESPECTS, aerial photography is one of the best ways of gathering information because so much detail can be crowded into a given area of film. The heart of this information-gathering capability is the gelatin-silver system. Since this system is one that you studied in the resident school, the purposes of this chapter are to upgrade your knowledge and to discuss how photoprocessing methodology can assure maximum information in each photographic negative and positive.

Not too long ago, the photographic laboratory technician had little to worry about when he or she considered the structure and other characteristics of the film to be processed. The general guidelines were enough to produce acceptable photographs. This has all changed since instrumented space vehicles have been used to record minute details on the surface of the moon and other planets in our solar systems. Much the same situation is present in this country's reconnaissance vehicles, which are capable of producing photographs from considerable altitudes. In both cases, the gelatin-silver system exposure, handling, and processing required considerable upgrading. Top quality work is now mandatory in specially designed laboratories in mixing and replenishing development solutions, and in handling film in automatic processing machines. In many imagery production facilities, top quality work—to make sure that all interpreters can read the maximum information from each reconnaissance exposure—is routine.

Although other systems can be used to reproduce aerial photographs, in this chapter we will confine our discussion to the gelatin-silver system of reproducing an image. We delve into the nature of the gelatin-silver system and examine its characteristics, particularly the measurements used for determining its quality.

1-1. Sensitometric Test Strips

In many imagery production facilities, the controlled processing of sensitometric test strips, as well as the measurement of exposure results, are functions performed by quality control technicians. The purpose of such controlled processing and measurements is to establish operating standards for that particular processing facility. These standards take into consideration the facility's equipment, degree of controlled environment, type of solutions used, and photographic materials. Even in a facility that does not require clean-room procedures to produce acceptable photographic products, the need for printing and processing controls is recognized. Here, sensitometric strips are made, processed, and analyzed daily to establish the necessary controls and to determine the need for replenishment of processing solutions for the next day's operation.

After making a sensitometric exposure, the image that results is determined by (1) the characteristics of the film being tested and (2) the characteristics of the process. Both of these factors are subject to change with time; but if one factor can be held constant, you can use sensitometric images to check and control the other. For example, your processing facility requires you to run sensitometric tests on each new type of film you plan to use, on each new batch of the films you regularly use, and, periodically, on your stock to detect deterioration because of age or storage conditions. For these tests, you make consistent, unvarying, sensitometric exposures and develop the tests under constant standardized processing conditions. Any changes in sensitometric characteristics should indicate a change in the film. You also run tests to check the performance of your production system (different machines, different technicians on the same machine, or different days on the same machine). In some imagery production facilities, a sensitometric exposed control strip, supplied by the quality control section, is taped at the trailing end of each roll of exposed material to be developed at a given gamma. In other imagery production facilities, a control strip is placed at the head, as well as the trailing end, of original film and only at the head, or beginning edge, of duplicating material. Aerial film may have an identification strip (about 5 feet in length), then a 3-foot "gray-scale" or control strip, and finally a 20-foot section of leader material spliced onto all incoming film to be processed. Because of mechanical operation of modern processing equipment, a 30-foot strip of fogged (but not processed) film is frequently attached immediately after the control strip for the purpose of testing for scratches. To certify automatic processing machine operation and establish a standard operating procedure, approximately 250 feet of controlled-fog scratch material can be attached to three sensitometric exposed control strips and processed through a designated machine. A close examination of the processed material and strips will reveal whether or not the machine is ready for processing mission film. If no scratches, pinholes, pressure marks, or uneven densities are present and if the gamma produced is within certification standards, you are ready to go. When you make sensitometric exposures on a control stock that you know to be uniform, the developed test indicates whether or not changes have occurred in the production parameter being tested.

800. List the requirements that a sensitometric processing machine must meet to conduct tests for controlled processing.

Controlled Processing. When you conduct tests (1) to determine film characteristics, (2) to evaluate changes in the product, or (3) to measure the effect on film of preexposure and postexposure storage conditions, you must exercise rigid control of the variables associated with processing. This generally requires using specially designed sensitometric processing machines.

A sensitometric processing machine must meet certain requirements. It must be capable of precision operation. That is, it must be able to give the same kind of development, at the same temperature, and with the same agitation, time after time, for as long as you desire. To achieve this, keep the tank capacities small, so that solutions are easily controlled and so that they can be economically discarded after each processing, thus minimizing the effects of deterioration of the solutions through use. By using small volumes of solutions, you can mix a great many batches of solution from dry chemicals, thereby minimizing the effects of changes in chemicals. Also, you can weigh and measure small quantities of chemicals more accurately than you can large quantities. Moreover, the smaller quantities can be mixed with less vigorous stirring, thereby reducing the danger of oxidation through aeration. Finally, the small volume of solution can be brought to the high-controlled temperature needed for precision testing with very little chance for error. The fact that the small tank capacity limits the amount of work that can be done at one time is of little consequence.

Agitation, in sensitometric processors, is critical. The processor must be designed to give complete and repeatable agitation to the strips being developed. To obtain repeatability, you must use some sort of mechanical agitation system; however, mechanical agitation can also work against you. For example, if your system uses an agitator that produces a regular, rhythmic motion, a constant wave is set up and the agitation can be uneven. To overcome this, properly designed sensitometric processing machines usually use more than one agitator. These agitators can be (1) a rocker, (2) an oscillating film carrier, (3) a moving vane, (4) a rotating paddle, or (5) a nitrogen gasburst diffuser. A popular combination of these agitators is the moving vane and the nitrogen gasburst diffuser.

Exercises (800):

1. When you are conducting tests to determine the characteristics of a special order film, what requirements must your sensitometer processing machine meet?

2. List the agitators that are usually found in a properly designed sensitometric processing machine.

801. State what you would do to insure uniform processing solutions for sensitometric test strips, and state how you should proceed with chemical batches to ensure repeatable performance.

Controlled Chemistry. To ensure uniform processing solutions for sensitometric test strips, set aside carefully pretested and certified chemicals. When these solutions run low, run a comparison test with other chemicals in order to obtain replacement solutions having similar properties. Cross-check each chemical batch with the previous batch to ensure repeatable performance.

You must certify all fresh mixes, using chemical analysis if necessary. And, of course, you must maintain control charts on the entire chemistry portion of your process.

Exercises (801):

1. How do you ensure uniform processing solutions for sensitometric test strips?

2. What procedure should you follow with chemical batches to ensure repeatable performance?

802. State how to match the sensitometric process with the production process, and explain analyze the process and how to adjust the controls.

Comparison with Production. When checking film characteristics sensitometrically for the purpose of controlling production, you must match the sensitometric process with the production process as closely as possible. This matching is done not only for the overall process but also for each stage of the process. Moreover, the sensitometric result at each stage of the test process should match that of each stage of the production process.

Begin by supplying the sensitometric processor with processing solutions capable of results identical to those obtained with seasoned solutions in the production processing machine. If you have matched the chemicals, all that is necessary to make the test match the production is to adjust the physical factors, such as time, temperature, and agitation. However, there may be times when these controls are not enough. Then, some slight changes in chemistry may be necessary. For production monitoring only, sensitometric strips are processed right along with the production film in the processing machines.

For any new process, or for an old process after some major change is made, run a series of tests to learn how the process is operating. This can be done by inserting as many sensitometric strips as possible with every run and recording the data for each strip. Do this over a sufficiently long period to enable you to arrive at a normal distribution. Once this has been done, you need only make periodic observations of your process, based on these sensitometric tests. For example, you may wish to determine the gamma obtained from one or more machines in your facility. Perhaps you're interested in the D_{min} and D_{max} (minimum and maximum densities) of each strip. Or, you may want to keep a continuous record of the base-plus-fog density of the photographic material on hand. For a time, you simply record your readings. When these are gathered over a period of time, any sudden or gradual changes in your recorded readings become apparent, and appropriate adjustments can be made.

If you plan to keep a control chart based on averaged daily readings, make the first plot at the end of the first day's operation. You can also set up a chart of ranges which are plotted at the end of each day's run. Using the range chart data, find the standard deviation of your process so that your sigma limits can be indicated on the control chart.

From your observations, you may note that the process is turning out products whose quality is somewhere between the 2-sigma limit lines. (Some laboratory facilities use the 2-sigma limit as their acceptance limits.) For tighter controls, you may want to place the limits inside the 2-sigma limits and reject any product falling outside your newly established limits. How do you decide where to place these limits? By observation, of course. Sensitometric test strips are associated with the negatives that they are supposed to control; but unless you actually examine the negative, you can never determine how close the association is. Because gamma is related to contrast, contrast is what you look for in the developed negative. If you consider the contrast related to gammas within 2 sigmas acceptable, then set this condition as your limit. But if you decide that the greatest (D_{min}) and the least (D_{max}) contrast you can accept lie closer to the centerline of your control chart, then set the acceptance limits to correspond with the acceptable gammas. From this point on, you keep the product with a gamma that lies within your limits and reject any product whose gamma lies outside these limits. You should retain the original 2-sigma limits so that you can determine whether or not the process is operating normally. Do not shut down a process or change the control unless the chart shows a trend away from the process average or unless your product falls consistently outside your acceptance limits. Because your facility may have already established acceptance limits, based on empirical knowledge, you should research the existing directives (e.g., technical operating procedures, standard operating procedures, or photographic operating instructions) to verify acceptance standards before changing the process or establishing new limits.

Exercises (802):

1. You are checking the film characteristics of a special order film sensitometrically for the purpose of controlling production. How do you match the sensitometric process with the production process?

2. You have modified a standard developer for your process and need to know how your process is operating. What procedure should you follow?

3. You have observed that your process is turning out products whose quality is somewhere between 2-sigma limit lines. You want tighter controls, how do you decide where to place your newly established limits?

4. How can you minimize the chance of incurring a processing error in production when the same error was counteracted in sensitometric testing?

803. Identify and explain the factors that control the day-to-day performance of production processing machines by sensitometric means.

Control Film Stock. To control the day-to-day performance of production processing machines by sensitometric means, you must rely upon a control film stock. The control stock is simply a uniform batch of film, generally all one emulsion number, of the same type normally used in production. You establish the standards for this control emulsion after repeated sensitometric tests of many film samples. When you find the emulsion that gives you the results you want, set it aside for test purposes.

Film stocks can be stored in deep-freeze units, capable of maintaining below-zero temperatures. If the film stock is to be used during the first 6 months of storage, then the refrigerator temperature and humidity can be kept at 50°F and 50 percent RH (relative humidity). Exposed sensitometric control strips, like film stock, can be kept in refrigerated storage until they are needed in production processing of film. Ordinarily, control-stock film that has been exposed, but not processed, should not be stored very long—usually no longer than 6 months. This rule of thumb applies to any aerial or ground mission film that has been exposed and processing-scheduled at the end of the mission in order to avoid any latent image deterioration.

A special situation occurs when sealed, film containers are opened to obtain film for sensitometric exposures. Once a container is opened, the film will either lose its inherent emulsion humidity, through excessive drying caused by arid climates, or acquire more moisture if exposed to the high humidities normally present in tropical climates. In either situation, it is best to open the film stock only after allowing enough time to properly acclimatize the film.

Primarily, this acclimatizing, or tempering, is practiced to prevent moisture from forming on the control stock. Like film stock, control strips are allowed to remain in the laboratory (after being removed from cold storage) until they reach room temperature. In the text table that follows, typical acclimatizing times are shown in hours for different sizes of film. Note that the times are much longer when film stock or control strips are stored in deep-freeze units. These times are given under the 100° temperature (T) differential usually present between storage area and laboratory room. Note also the increase in time when bulk film, such as a carton of 10 rolls, must be acclimatized.

	25° T Diff	*100° T Diff*
35-mm (single roll)	1.5	3
35-mm (10-roll carton)	12	10
70-mm (single roll)	2	6
9-inch (180-foot roll)	12.5	—

Times, shown in the table above, assume that laboratory conditions can run as high as 70 percent RH. When humidity reaches 90 percent, times given in the table should be doubled to avoid condensation on film stock or control strips taken from a refrigerator. Storage of control strips usually follows the rules laid down for storage of unexposed film. These rules are given in TO 10J–1–4, *Storage, Issue, and Shipment of Film, Paper, and Chemicals.* While sensitometric control strips can be frozen, you will find that, in normal production, processing schedules are such that only refrigerator facilities are used for control strips to avoid long periods of storage. Even though you take all the necessary precautions to protect your control stock, there are several things connected with its use that you should know. Among these are the following:

a. Photographic films, whether or not they have been exposed, are not stable. Although storing film at low temperature inhibits deterioration from age, complete stability cannot be attained. Therefore, you cannot expect a control stock to be reliable indefinitely.

b. After exposure, a growth or decay of the latent image can occur so that, in time, the developed image will be very different from that which is expected. You must not only critically control the storage conditions for exposed test strips, but must also be careful that you do not keep the strips too long before using them.

c. You cannot expect any large batch of film, even though it may have a single emulsion number, to be entirely uniform throughout. Variations in the sensitivity and, consequently, the photographic response occur in the coating. Rather than trying to select film with no variations, many technicians randomly select samples of emulsion coatings in order to average any variations.

In addition to the errors caused by variations in control stock, there is another source of error present in processing. For example, if an error in temperature is counteracted by an error in agitation, a sensitometric test may show the processing conditions to be normal when they are not. Although the effects of these two off-standard conditions counteract each other in the control emulsion, you cannot assume that they will do so in the production emulsion. To minimize errors of this sort, you must not rely on sensitometric test strips alone. You must also monitor the chemical concentrations, as well as the mechanical and physical controls that include time, temperature, agitation, replenishment, etc.

Basically, the main purpose of doing controlled processing of sensitometric test strips is to hold one group of variables constant while studying the changes that may occur when using another group of variables. You should realize that while such control and measurement furnish you with a close approximation, sensitometric processes are not always repeatable, nor are control stocks perfectly stable. To some extent, individual sensitometric results are always influenced by secondary factors that you would ordinarily expect to be constant. Because this interaction is always present, use the statistical methods to help you achieve an adequate and reliable process control.

Exercises (803):

1. What must you rely upon to control the day-to-day performance of production processing machines by sensitometric means?

2. How do you establish the standards for the control film stock?

3. What is the main purpose of doing controlled processing of sensitometric test strips?

4. Until needed, under what conditions is sensitometric control film kept?

5. To what natural causes can you sometimes attribute errors occurring in sensitometric control strips?

1-2. Sensitometric Instrument Operating Care

The sensitometer and densitometer are the basic tools for photographic process control. To do the work which they are intended to perform, they must be maintained in perfect working order. Indeed, inaccurate measurements may be worse than none at all, since they can lead to a considerable waste of time and effort and costly process adjustments. A strict maintenance program for these instruments is, therefore, a prime requisite for successful process control. The information given below should help you establish such a program.

804. Name and explain briefly the factors required to produce an exposure when using a sensitometer.

Control and Maintenance of Sensitometers. The exposure produced on the film in a sensitometer depends upon the intensity of the light source, its distance from the film, the time of exposure, and the amount of absorption of light caused by various optical elements, such as glass plates, mirrors, filters, and the step-tablet modulator. In symbols, we can express this by the equation:

$$H = \frac{i \cdot T_f \cdot T_{gp} \cdot R_m \cdot T_{st} \cdot t}{d^2}$$

where

H = exposure.
i = intensity of light source in candlepower as seen from the center of the step-tablet position.
T_f = luminous transmittance of filters in beam.
T_{gp} = transmittance of any glass plates in the system, such as under the step tablet.
R_m = reflection of mirror, if present.
T_{st} = transmittance of step tablet.
d = distance from lamp to film plane in meters. (This is shown in the equation as d^2 because the illuminance decreases as the square of the distance.)
t = exposure time in seconds.

Since the graphical representation of sensitometric data uses the logarithm of the exposure rather than the exposure itself, the above equation expressed in logarithmic form becomes:

$$\log H = \log i + \log T_f + \log T_{gp} + \log R_m + \log T_{st} + \log t - 2 \log d$$

Most of the sensitometers in use today are the type IB; that is, they are intensity-scale, nonintermittent instruments using stepped exposures. The exposure given to a particular product on such a sensitometer is often stated in terms of log H_{11}, the logarithm of the exposure in meter-candle-seconds produced through the eleventh step of a 21-step, intensity-modulating tablet. Under these circumstances, the term "log T_{st}" in the above equation is then replaced by D_{11}, where D_{11} is the density of the eleventh step of the tablet. If optical elements are included in the system, these must be accounted for. In setting up and maintaining the sensitometer, it is necessary that each of the terms in the above equation be known and precisely controlled against change.

Candlepower can be measured on a photometer bench by comparing the sensitometer lamp with a calibrated standard lamp. Such lamps are calibrated as to the candlepower they produce when operated at that current or voltage to produce a specified color temperature. It has been found that constant-current operation produces a more nearly constant light output than does constant-voltage operation. In addition, the slightly yellowish deposit of evaporated tungsten inside the lamp envelope is somewhat compensated for by the increasing filament temperature caused by passing a constant current through the diminishing diameter of the filament wire. Therefore, in spite of the fact that candle-power varies somewhat more rapidly with changes of current than with equal percentage changes of voltage, constant-current operation is preferred.

In a photographic laboratory, one or more calibrated lamps may be kept as standards against which sensitometer lamps can be compared at intervals in the sensitometer, either physically or photographically. For photographic testing, several filmstrips are exposed with the working and standard lamps and are processed together. Densitometry of the processed strips will then show what differences, if any, exist between the lamps.

A visual photometer can be assembled rather inexpensively from a barrier layer cell and a good quality microammeter. The photocell is usually covered with Wratten filter No. 102 (or equivalent filter) to convert its spectral response to that of the eye, since exposure intensity is expressed in visual units. With the photocell placed in the exposure plane of the sensitometer, compare the working lamp with a standard lamp by noting the deflections of the microammeter produced by each lamp. Use a jig to position the photocell accurately in the exposure plane of the sensitometer. Exact location of the photocell is important for precision in such measurements.

Color temperature can be checked by using a color temperature meter to compare the working lamp with standard lamp. However, since candlepower changes much more rapidly with lamp age than does color temperature, the lamp will probably be discarded because of low or unreliable output before a color temperature change becomes serious.

For those sensitometers with optics in the light path, it is necessary to use either the physical or photographic methods outlined above to establish and control log H. This is true because the initial calibrations are dependent upon the light-gathering power of the optics, and control is dependent upon their cleanliness and continued adjustment. In these instruments, the positions of the lamp and the parts of the optical system are extremely critical.

The distance from lamp to film plane is usually measured by a calibrated scale; once the zero of the scale has been set to coincide with the film plane and the index has been set at the lamp filament position, no maintenance should be necessary other than an occasional check to see that neither has moved.

The luminous transmittance of filters is calculated from spectrophotometric curves. This job is most likely to be done by an independent standardizing laboratory or the filter manufacturer. Wherever possible, use glass filters because of their stability. Such filters need only routine cleaning to keep them in good working order. Gelatin or acetate filters can be checked photographically for fading by comparing them periodically with similar filters, preserved as standards.

In process control, it is usually more important that the sensitometer exposure remain constant than to be accurately known. Therefore, any mirrors, glass plates, etc., in the sensitometer must be kept clean but need not be actually measured for transmission or reflection. Approximate values of 4 percent loss for each glass-air surface and 93 percent reflectance for a rear-surfaced silver mirror can be used.

The step tablets, whether they are of the photographic silver or colloidal graphite type, are quite stable; however, they must be protected from scratches and kept clean. The densities of the individual steps can be checked periodically with a good densitometer.

Exposure time is usually determined by the passage of a slit or sector wheel driven by a synchronous motor. Because the frequency of commercially available power is carefully controlled, the motor speeds are quite constant. However, bearings should be oiled and couplings should be kept tight to ensure that the motor is not overloaded and that its motion is transmitted to the timing aperture without slippage.

In the case of scanning-type instruments, it is especially important that ways and bearings be properly lubricated and kept in adjustment to avoid irregular motion of the traveling lamp house and timing slit. Such irregularities produce exposure variations along the film aperture which result in density "pickets" running across the film.

It is important that all film samples are exposed at or near the same temperature. Meet this condition by operating the sensitometer in an air-conditioned room or, in extreme cases, by adding cooling or insulation to the film holder of the sensitometer. A difference of 30°F. in the temperature at the time of exposure can cause as much as 0.07 log H change in the apparent speed of certain films. This temperature variation is not uncommon among high-intensity sensitometers when artificial cooling is not provided.

Since the principle of operation of sensitometers is well known to imagery production personnel, this section deals with just two instruments, each embodying a different system for producing exposures in sensitometric test trips. Because they operate in different spectral ranges, these instruments are often found together in photographic laboratories. One instrument uses an incandescent light source and can produce exposures of relatively long duration; while the other instrument produces extremely short, highly actinic exposures. Having both types of sensitometers enables you to produce test strips that conform quite well to most practical situations.

USAF central calibration facility (AFCCF). The levels of quality obtainable from reconnaissance missions vary with the sensitometric system, the operating conditions, recording media, processing and printing characteristics, and other related factors. The capabilities of the supporting facilities also vary according to their assigned mission. Therefore, variations must be identified in order to set up quality controls and to make sure that the greatest amount of information is derived from the imagery.

Sensitometer calibration is accomplished with calibration kits provided by AFCCF. The kits are used by photographic laboratories to determine if they meet calibration requirements. The sensitometer calibration kits are produced by the Hill AFB Audiovisual Services and shipped with a special dry-ice pack by the fastest and most direct means. The Engineering Section of the Photo Reconnaissance Intelligence Program Management Branch provides technical support in preparing support documentation, maintaining records, and providing calibration results to the user.

The sensitometer calibration kit consists of two rolls of film (one exposed with a series of step wedges by the CCF sensitometer and the other unexposed), instructions, labels, and packaging. The exposed roll is exposed with light simulating the sensitometer being calibrated. For example, the bit calibrating the EG & G type of sensitometer is exposed using a filter which alters the effective color temperature of the CCF standard tungsten lamp to a close approximation of the xenon lamp of the EG & G type of sensitometer.

After receiving the sensitometer calibration kit, the user exposes his or her step wedges. The step wedges are aged, processed (1 each, side-by-side), and plotted. From this plot the actual light output in meter-candle-seconds (MCS) of the user's sensitometer can be determined quite accurately, since all equipment used in the CCF program is directly traceable to standards established by the National Bureau of Standards (NBS). Read TO 10-1-6-2 for more information and detailed procedures.

Exercises (804):

1. What factors must you consider when determining the exposure produced by a sensitometer?

2. Identify the type IB sensitometer.

3. By what means can you detect changes in the light source of a sensitometer? What results will be detectable in the sensitometric test strip?

4. What particular property of a lens or optics do you rely upon when you calibrate a sensitometer?

5. Of what importance is temperature when making a series of sensitometric exposures?

6. What is the advantage of having two sensitometers operating in different spectral ranges?

805. State why the electronic flash sensitometer is best suited for establishing process control.

The Electronic Flash Sensitometer. Figure 1-1 illustrates this instrument as a light source for applying a graduated series of known light intensities to a photosensitive material. This series of exposures helps to determine emulsion characteristics, such as photographic speed, range of tone, contrast, color balance, fogging, and age. The sensitometer may be used also to determine the effectiveness of the developer and the development method used.

It is characteristic of the electronic flash sensitometer that neither the intensity nor the color of its light source deteriorates with time. Furthermore, a voltage regulator prevents changes in output due to line voltage fluctuations. Thus, experiments can be repeated under identical conditions.

The light intensities available with the flash sensitometer are sufficient to test both slow emulsions, such as enlarging paper, and fast emulsions, such as high-speed panchromatic film and color film. The flashtube emits light about the color quality of daylight and requires no color compensation.

Performance characteristics. The E.G. and G. model Mark IV operates on standard 110-volt, 60-cycle AC power. It is equipped with three circuits to permit exposure times of 10^{-2}, 10^{-3}, and 10^{-4} seconds. For processing control, you must choose the flash duration that most closely approximates the exposure given in film to be processed. The 10^{-3}-second circuit is the most powerful, with an output of approximately 7000 meter-candle-seconds. The 10^{-2}-second and 10^{-4}-second circuits produce approximately 1300 and 130 meter-candle-seconds,

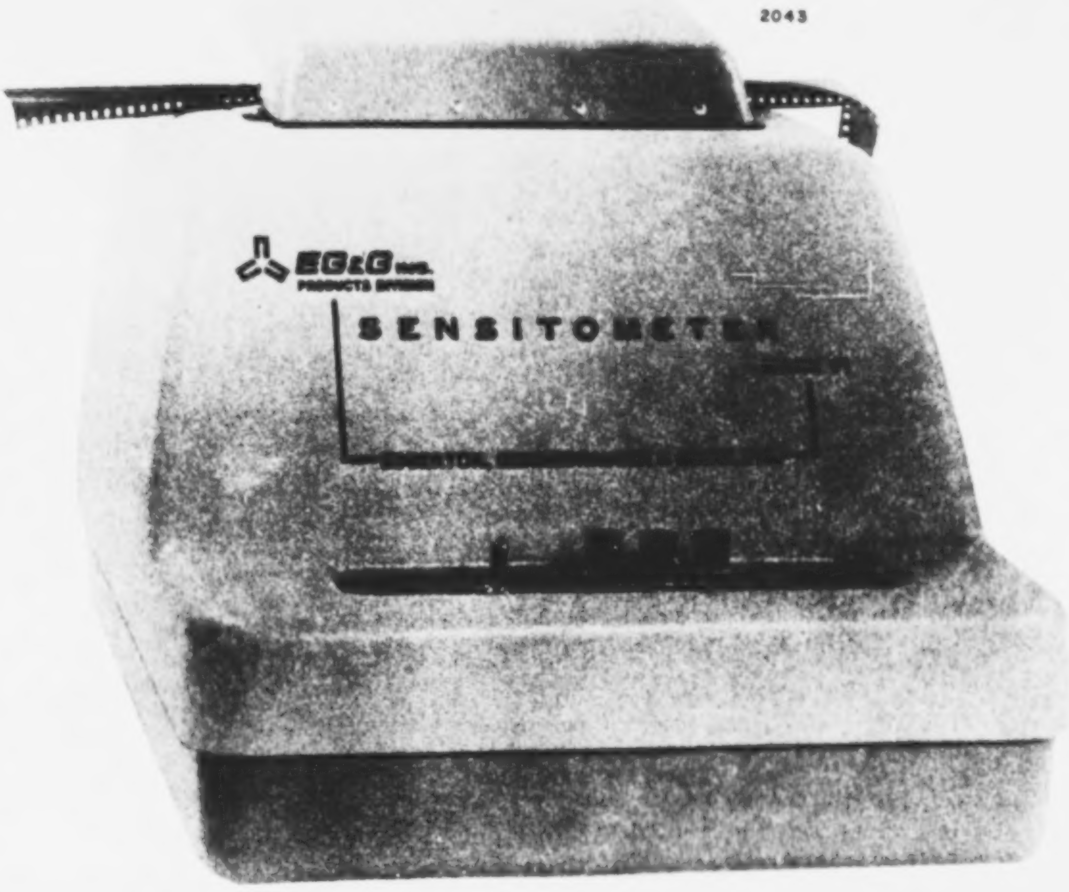


Figure 1-1. An electronic flash sensitometer.

respectively. The output can be tested by means of a calibrated light meter.

Two compensating attenuators (which can be seen in fig. 1-2) are provided to equalize the output from the three circuits. For ordinary use, they may be considered as equivalent to DN 1.0 and ND 1.7 filters. Their application for specialized studies is discussed below. The compensators have been calibrated against a standard laboratory sensitometer and will equalize the three circuits to within ± 10 percent. Since each instrument is slightly different, however, the attenuation may not be exactly the same for the three circuits in any one unit. Should the exact attenuation values be required for a particular application, the manufacturer will provide calibration figures for each compensator, at a nominal charge.

The light intensity of any circuit can be controlled by means of optical filters (such as the Wratten 96 series) inserted between the flashtube and the photosensitive emulsion. The following text table presents a general guide for filtration necessary with films of different ASA ratings. For comparison of different exposure times, the filters should be used in addition to the appropriate compensating attenuators.

ASA Index	*ND Filter*
0.3	0
1	0.5
20	1.5
50	2.0
200	2.5
500	3.0
2000	3.5

The evaluated exposure difference between one end of the exposure window and the other is 0.03 log unit, or about 6 percent.

A charging time of 5 seconds should be allowed between flashes. Variations in voltage between 80 and 130 volts do not affect the light output. The maximum detectable variation in flashtube output between flashes is 0.01 log unit. A continuous test was performed on this instrument, during which the 10^{-3}-second circuit was triggered at 10-second intervals for a total of 200,000 flashes. Even after this continuous service, the light output had decreased by only 15 percent.

Specialized uses. The electronic flash sensitometer may be used to test photosensitive emulsions for reciprocity

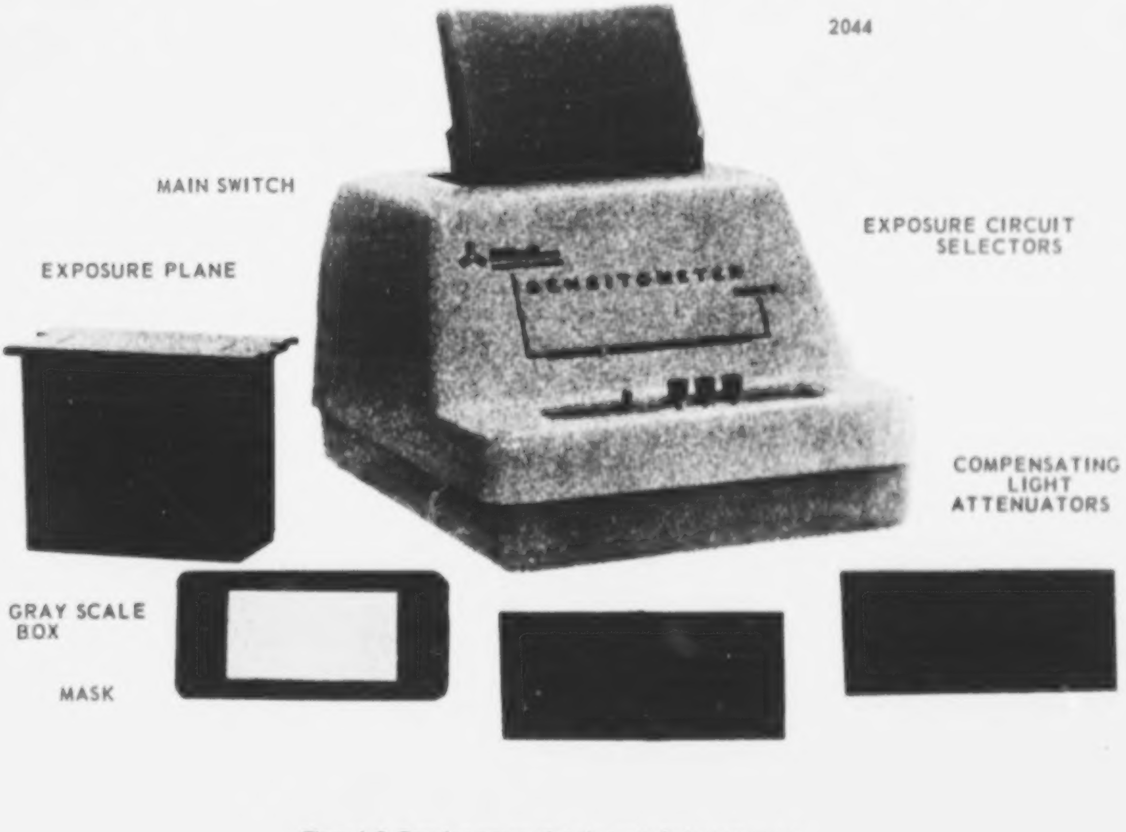


Figure 1-2. Complete system of an electronic flash sensitometer.

failure. The two variable area filters (fig. 1-2) provided with the instrument reduce the output of the 10^{-2}-second and 10^{-3}-second circuits to that of 10^{-4}-second circuit, permitting direct comparison of the three different exposure durations.

The 10^{2}-second pulse may be used without color compensation for exposing daylight-type color film. If it is necessary to attenuate the light in order to obtain the proper exposure level, ordinary "neutral density" filters should not be used. Filters such as the Wratten 96 series, although satisfactory for normal exposure of black-and-white film, are not completely neutral and are not suitable for use with color film. For these applications, variable area filters of the type provided with the sensitometer must be used.

Operation. A 21-step tablet is included with the instrument. The steps range in density from 0.05 to 3.05 in increments of approximately 0.15. The exact density of each step must be measured by the user.

For convenience in reading the processed film, number each step of the tablet at one edge. Place the tablet over the exposure window, emulsion side up. Insert the ends of the tablet into the space at each end of the window. To prevent damage from excessive handling, leave the tablet in place at all times.

To expose a photosensitive emulsion, you accomplish the following steps:

(1) Plug the power cord into a 110-volt, 60-cycle AC outlet. Be sure to ground the plug to prevent shock hazard.

(2) Switch the power on.

(3) Press the switch for the desired flash duration.

(4) Add filters if necessary. To change filters, remove the gray-scale box completely from instrument. Drop the filters into the cavity over the light source and replace the gray-scale box. When replacing the box, make sure the flange is to the rear; otherwise, the box will not seat properly, and it will not be possible to make an exposure.

(5) Turn the room lights off.

(6) Place the film to be exposed over the step tablet, emulsion down.

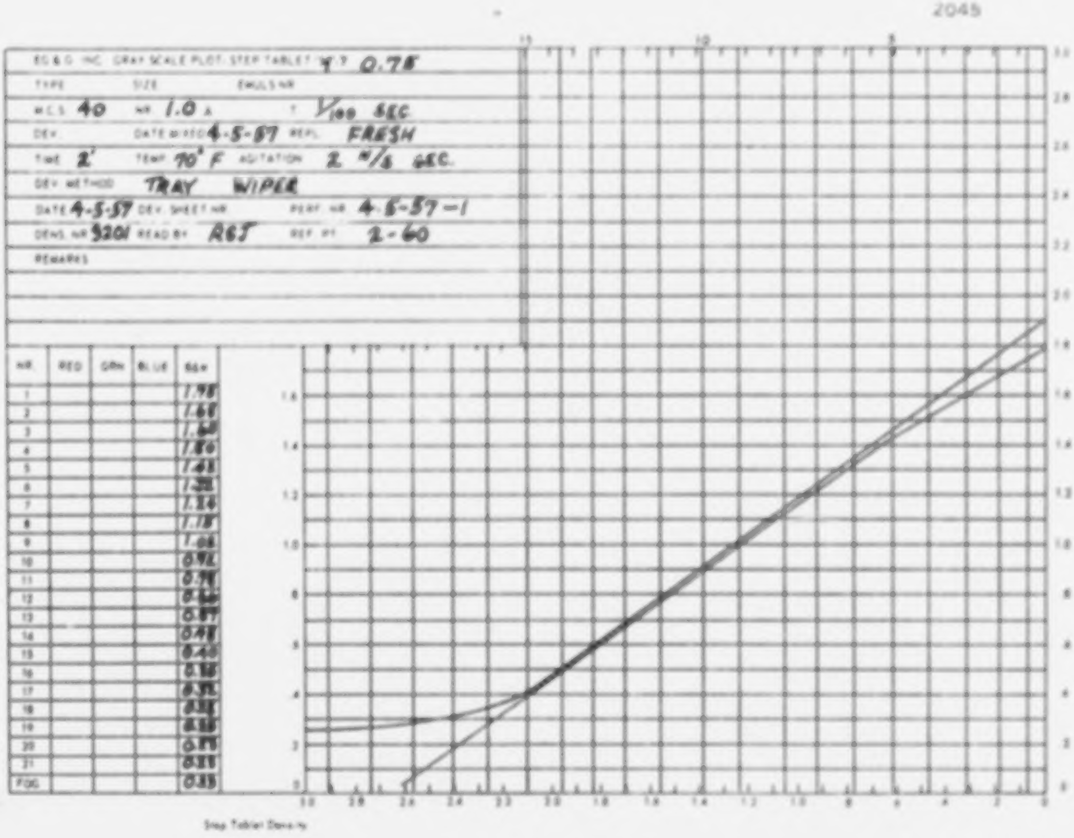
(7) Hold the filmstrip in the grove.

(8) Hold film in place at one end and lower the cover.

(9) Push the cover down until a clicking sound indicates that the tube has flashed. A small amount of light may be visible at the edges of the cover but will not damage the film. If there is a large light leak, check the setting of the microswitch. If the microswitch is set too low, the tube will fire before the platen covers the film.

(10) Process the film as usual.

For an example, we have included a master gray-scale plot of the type used at the factory. Figure 1-3 is the master as it originally appears. After the densities on the step tablet



EG&G INC. GRAY SCALE PLOT-STEP TABLET NR 0.75
TYPE SIZE EMULS NR
M.C.S. 40 NR 1.0 T 1/100 SEC
DEV DATE MIXED 4-5-57 REPL. FRESH
TIME 2' TEMP 70° F AGITATION 2 W/S SEC.
DEV METHOD TRAY WIPER
DATE 4-5-57 DEV. SHEET NR PERF. NR 4-5-57-1
DENS. NR 9201 READ BY RGJ REF. PT 2-60
REMARKS

NR	RED	GRN	BLUE	B&W
1				1.78
2				1.66
3				[illegible]
4				1.50
5				1.43
6				1.28
7				1.14
8				1.15
9				1.06
10				0.92
11				0.78
12				[illegible]
13				0.57
14				0.48
15				0.40
16				[illegible]
17				0.32
18				[illegible]
19				[illegible]
20				0.17
21				0.11
FOG				0.13

Figure 1-3. A gray-scale plot.

have been measured, a vertical line should be drawn at each density value. The numbers across the top of the graph indicate the step numbers. In the example, the density of step 5 is 0.63; so a vertical line is drawn at 0.63 on the horizontal axis. The plot is now ready for use in processing control. As shown in figure 1-3, the densities read from the gray scale on the processed film are recorded in the table and the points are plotted on the graph. The development gamma is determined as the slope of the straight line drawn through the central portion of the gray-scale curve.

Maintenance. On occasion, the flashtube may need replacement. To replace the tube, remove the gray-scale box and the protective glass tube shield and carefully pull the tube out horizontally.

CAUTION: There is danger of severe shock if the tube is removed immediately after use. To prevent shock, the power switch should be in its OFF position. Wait at least 2 minutes before removing the tube.

The red dot at the top of the tube socket indicates the correct position for the trigger electrode. Insert the new tube with the trigger electrode at the top. Replace the tube shield and the gray-scale box, making sure the shield rests on its sponge rubber support. This is the extent of operator maintenance. Any servicing beyond changing a tube must be done by 404X0 maintenance personnel.

Exercises (805):

1. Why is the electronic flash sensitometer best suited for establishing processing control?

2. A graduated series of exposures from the electronic flash sensitometer helps to determine what emulsion characteristics?

3. What are two characteristics of the electronic flash sensitometer?

806. Describe the Herrnfeld sensitometer and state its operational characteristics.

The Herrnfeld Sensitometer. This instrument, shown in figure 1-4, uses an incandescent light source and operates in an exposure range from 1/20 to 1/100 second, and it is used for both sensitometric evaluation and processing control. Its exposure plane is an arc of a circle, and the exposing light is distributed uniformly over the exposure plane by means of a rotating tube.

Description. This particular sensitometer is a type IB instrument designed for both the evaluation and control of photographic material. It uses a commercially available photographic step table (Kodak No. 3) as its intensity modulator and a wedge contained in a semicircular exposure plane. The light source may be any lamp having a medium prefocus base, a light center of 2 3/16 inches, and an envelope diameter of not greater than 1½ inches. While a T12 lamp may be used, the preferred lamps are:

100	watts PH/100T81/2P
200	watts PH/200T10P
300	watts PH/300T10P
500	watts PH/500T10P
1000	watts PH/1000T10P

The light output of the sensitometer is proportional to the wattage of the lamp. A 1000-watt lamp delivers about 16,000 foot-candles at the exposure plane. The lamps listed above are all rated at 3200 K when burning at 120 volts. There are two advantages to be gained when burning these lamps at 80 percent of their rated voltage (96 volts). First, you reduce their temperature to 2970 K, which is a more desirable color temperature for positive black-and-white and color films, and second, you increase the usable life of each lamp by 1900 percent. The Herrnfeld model 160–1D daylight conversion filter changes the 2970 K temperature to daylight temperature.

The lamp is contained in the body of the instrument, and its light passes through the optical system, shown schematically in figure 1-5. The light is distributed across the underside of the modulator by means of a revolving rectangular tube. The exposure time is controlled by adjustment of the slit aperture located at the end of the light distributor. By changing the width of the aperture, the following exposure times can be obtained:

Time	*Aperture*
1/20 sec.	0.600 in.
1/30 sec.	0.400 in.
1/50 sec.	0.240 in.
1/60 sec.	0.200 in.
1/75 sec.	0.160 in.
1/100 sec.	0.120 in.

The use of exposures shorter than 1/100 second is not recommended.

Operation. After you plug the power cable into a 115-volt AC outlet and turn on the toggle power switch on the dial plate, the voltmeter is set to 98.5 volts (fig. 1-4). Start the light distributor rotating by turning on another toggle switch, located just in front of the exposure plane housing.

Check the lamp by depressing the test button located on the left side of the instrument. This action starts the lamp, and it will continue to operate as long as the button is held down.

WARNING: Be decisive in your movements when pressing this button. Partial pressure will cause the instrument to chatter.

Place a film sample on the exposure plane, lower the hinged platen, and make an exposure by depressing the operating switch. Be sure to hold the button down until the instrument clicks twice. (The clicking is the solenoid operating, and the sound is rather loud.) Depressing the button opens the shutter automatically when the lamp distributor is in the proper position to make the exposure. The shutter closes when the light has swept completely

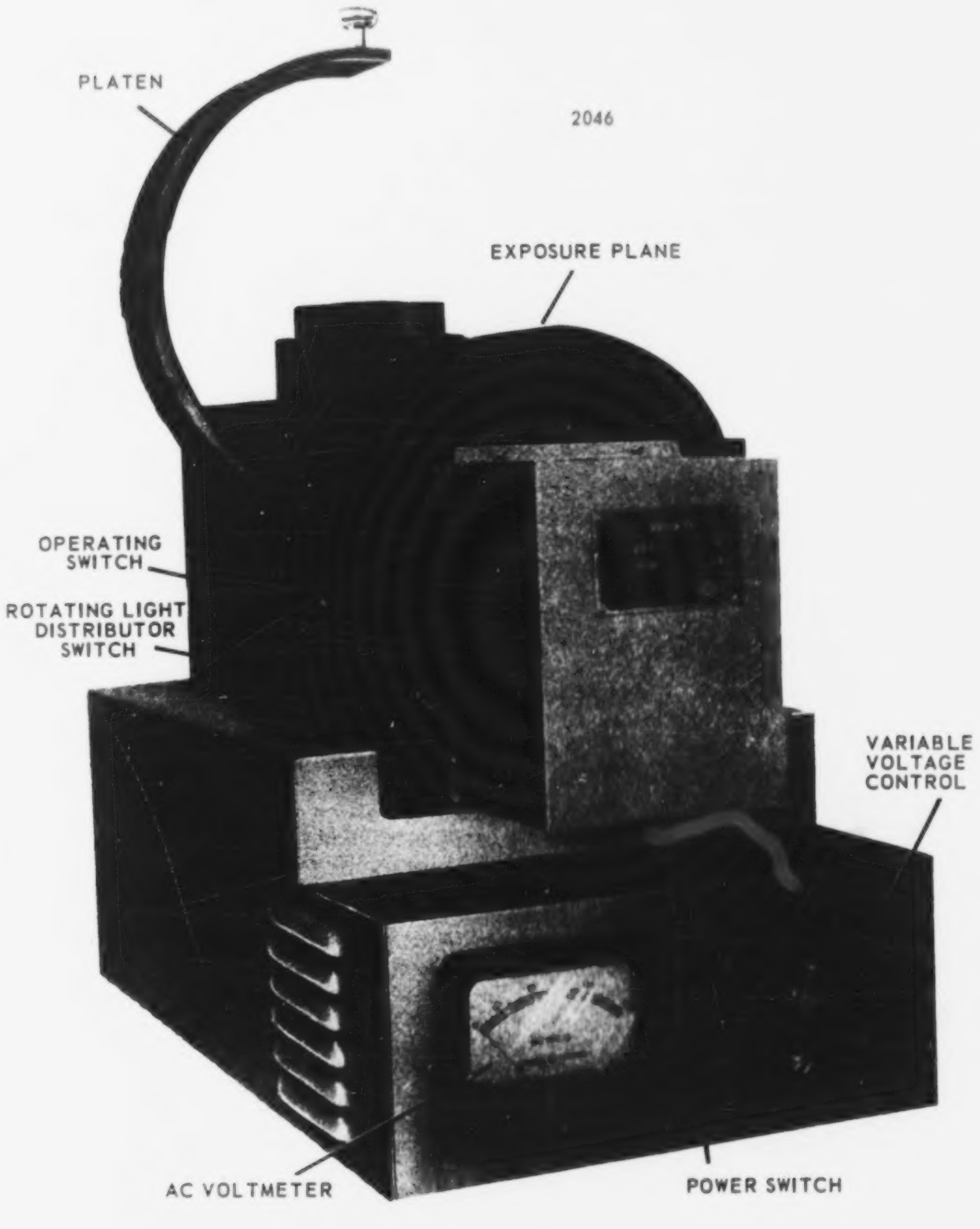

PLATEN
2046
EXPOSURE PLANE
OPERATING SWITCH
ROTATING LIGHT DISTRIBUTOR SWITCH
VARIABLE VOLTAGE CONTROL
AC VOLTMETER
POWER SWITCH

Figure 1–4. The Herrnfeld sensitometer.

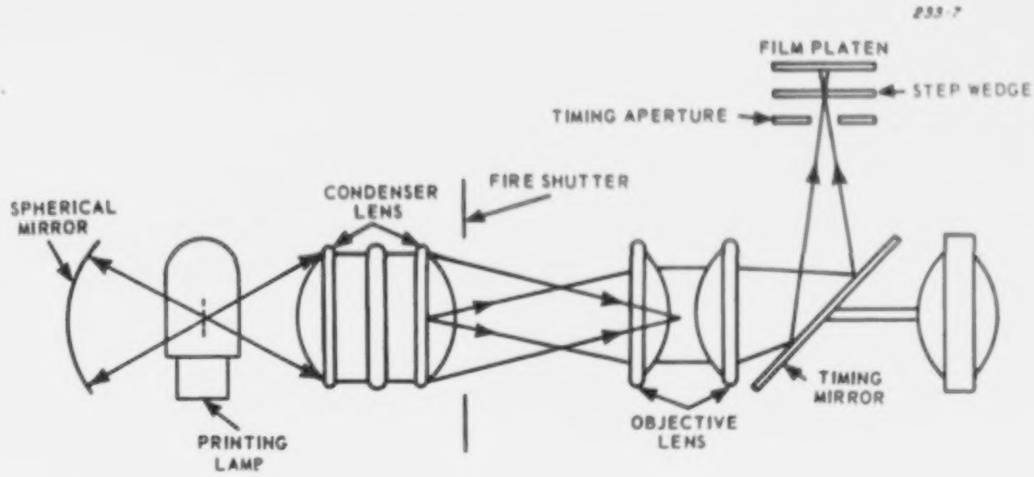


Figure 1-5. Schematic of the Herrnfeld sensitometer.

across the exposure plane. By holding the button down, you cause the cycle to repeat.

Exercises (806):

1. What type of an instrument is the Herrnfeld sensitometer?

2. Name two characteristics of the plane of exposure.

3. Under what exposure range does the instrument operate?

4. Why should you be decisive in your movements when depressing the test button on the instrument?

807. Identify the characteristics and procedures for control, calibration, and maintenance of a densitometer.

Densitometer Control and Care. In imagery production, densitometers of all types play a vital role. For routine processing control in low-volume installations, the simpler instruments—such as the Macbeth Quantalog and the Welch Densichron—are used extensively. In high-volume laboratories, instruments such as the Quantascan automatic densitometer are needed. In this section, we discuss the care and operation of the Quantalog densitometer.

A good method for control of a densitometer is to use several steps of a photographic silver step tablet or sensitometric strip for checking the instrument. To establish control, the tablet or strip is first calibrated by making measurements on the densitometer for at least 20 consecutive working days. During these 20 days, the instrument should have operated in a "normal" manner (without serious shifts in level or instabilities). If major alterations are deemed necessary, such as replacement of a photocell or amplifier tube, another base period should be used. At the end of a satisfactory base period, the check readings are averaged for each step on the strip. These averages are the "precision control levels" for each step on that check strip for the instrument. Control charts then may be drawn for the densitometer.

On a typical control chart, time (in days) is plotted on the abscissa and check readings plotted along the ordinate. The precision control level is drawn as a solid horizontal line on the chart. This chart, however, will have greater value if control limits are shown. By indicating these control limits, you can instantly see whether a check reading is "in control" or "out of control."

An out-of-control reading differs from the control level by more than a normal expected amount. This amount, called 3-sigma, is determined from the variability found in the 20-day base period data by making a simple statistical computation. Such control limits are drawn as horizontal dotted lines at 3-sigma above and below the control means.

When a daily reading falls outside the control limit, the densitometer has varied significantly more than it did during its 20-day base period, since there is only one chance in a thousand that it could have happened by chance alone. The cause of such a significant variation must be found and corrected before the densitometer is used again for routine work. Practical considerations, however, may dictate the adoption of other criteria. If the amount of variation allowed by these limits is too great to be tolerated in using the densitometric data, then densitometer improvements must be made. On the other hand, if the normal precision of the instrument is better than that required, wider control tolerances are justified.

The Quantalog densitometer is used to measure densities on both black and white as well as color materials.

The Quantalog instrument. This is one of several instruments made by the same company. The TD series of instruments is designed to measure transmission densities, whereas the RD series measures reflection densities. In this section, we will discuss the TD-102 model of the Quantalog densitometer, which is shown in figure 1-6.

The Model TD-102 instrument has a movable snout that contains a collective core. This snout is lowered onto the film sample by a lever and raised away by a return spring. Action of the snout is precise so that operator variables are cut to a minimum. The scale of this densitometer is linear (with evenly spaced graduations) to make density reading easier and more accurate than is possible with densitometers having nonlinear scales.

The total power consumed by this instrument is 60 watts. The wattage includes the power needed to operate the electronic circuits, the optical system light source, and the antifatigue lamp. The power transformer is designed to operate on either 115 or 230 volts and at powerline

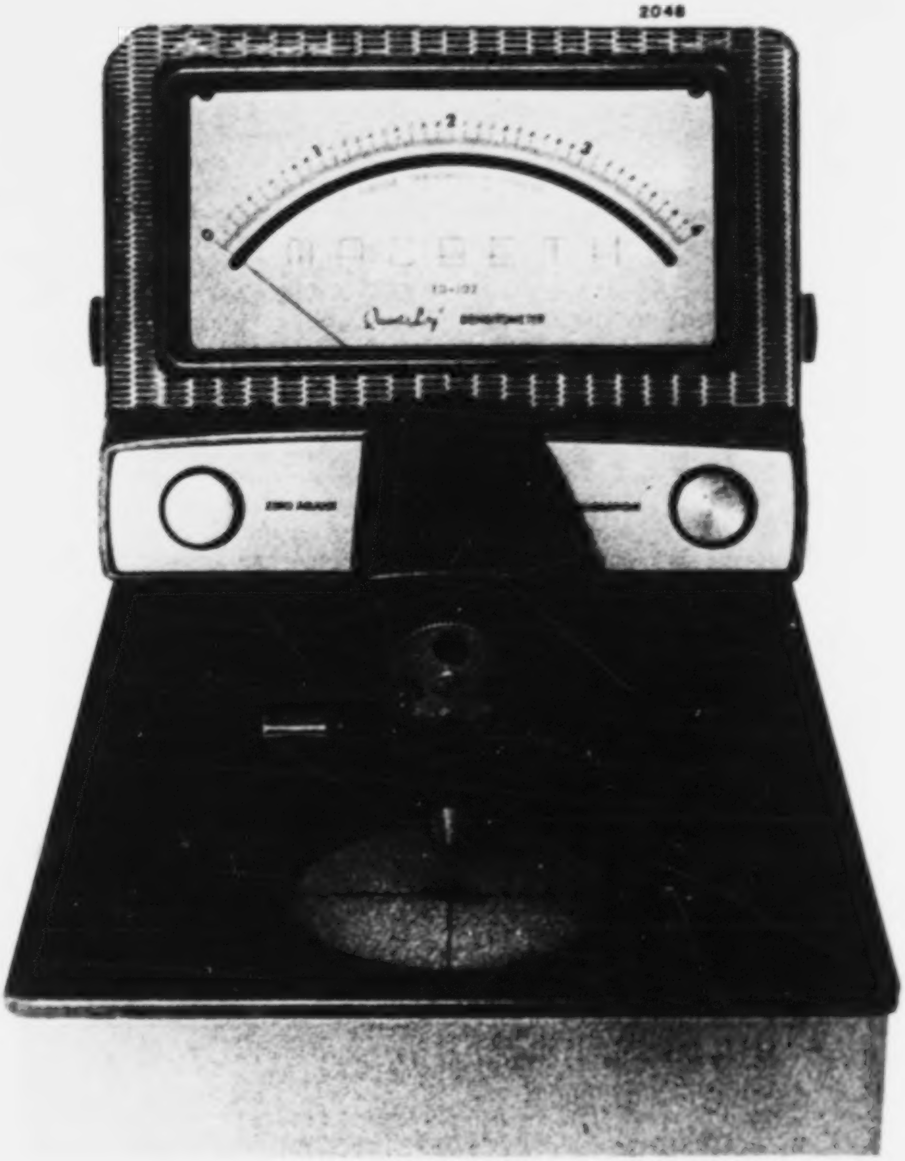


Figure 1-6. The Quantalog densitometer.

frequencies that may fluctuate between 50 and 60 cycles per second. Always check the data tag on the back of each instrument for the specific operating voltage for which its transformer primary has been wired.

The power supply of the TD–102 is self-regulated and hence not affected by minor line-voltage variations. However, these variations will affect the stability of the energy radiated by the optical system's light source. It is best if you use a voltage regulator to prevent these fluctuations, which may cause reading errors. For this purpose, a simple 60-watt regulator is adequate.

The densitometer is designed for operation under all normal conditions of ambient illumination. Its performance is unaffected when used in either a darkroom (meter scale is not illuminated; therefore, some form of illumination is required when reading the scale under these conditions) or when used by a sunlit window.

The performance specification for the TD–102 with respect to its optical system is that the geometry meets the requirements given in ANSI Standard PH 2.19–1959, *Measuring Diffuse Transmission Density*. The instrument is equipped with a color filter turret in which four filters can be positioned. Filters that are installed in three of these positions are of the Wratten series recommended for 3-filter color densitometry. (These filters are normally Wratten Nos. 92, 93, and 94, used for red, green, and blue density measurements, respectively.) A fourth filter, Wratten No. 96, can be used for making visual density measurements. The color filter turret is easily removed without tools, and additional filter turrets are available which can be equipped with special-purpose filters. Such additional turrets should be obtained through your supply channels.

All meter readings are made directly from a single scale. This eliminates the reading errors that can be made when using an instrument that requires range changing. A mirrored meter scale enables you to make accurate and reproducible readings, since parallax readings are avoided. The linear density scale, with a range from 0 to 4.0, is divided into 200 graduations—each equal to 0.02 density units. Instrument readings are precise within a tolerance of 0.02 density units, and reliable readings can be made with a repeatability of ±0.01 density units.

On the circular stage diffuser, there is a brightness of approximately 100 foot-lamberts. The circular stage has a 3¾-inch diameter. A circular aperture of 2mm (0.0787 in.) is installed, and it is removable for replacement with three sizes being supplied. Maximum temperature at the aperture is about 40°C (105°F).

Size of the film sample to be read is governed by the throat clearance. Throat clearance of this instrument is 11 inches, making it possible to read to the center of any sample up to 22 inches in width, and of any length. Instrument performance is essentially independent of sample thickness.

Operation. The operating controls for this transmission densitometer are located on the front of the main electronics housing and on the photomultiplier housing, both of which are shown in figure 1-6. This arrangement makes the densitometer control easy to see and within easy reach. The function of these operating controls is given below, and they are operated in the order in which presented:

(1) Zero adjust control performs a dual function in that it is a combined power (ON-OFF) switch and a zero adjustment of the needle on the meter. This control is turned in a clockwise direction and in conjunction with the snout lever and the filter selector control. The lever must be fully depressed while the filter control is turned to the visual filter position. Make sure that the gold filter trim control knob is in its bottom position. You will find that, with no sample over the aperture, the meter needle will point below the zero mark until the snout lever is fully depressed.

(2) The filter trim controls (of which there are four) permit you to trim each of the filter positions individually. Turn each of the filter selector controls in sequence (gold, red, green, and blue) until the respective filter trim control knob is in its bottom position. After the bottom position is reached in each case, the snout lever is depressed so that the filter selector control can be adjusted until the meter reads zero.

(3) The calibration control adjusts the meter pointer to read a specific up-scale density for which the densitometer was calibrated at the factory. This adjustment can only be made with the aid of an internal calibration reference placed in the measuring beam. This placement is aided by moving the calibration reference control backward until a click is felt. You will find the reference control at the bottom right-hand side of the photomultiplier housing. After the snout lever is pressed down, the calibration control is adjusted until the density reading on the meter is the same as that shown on the tag adjacent to this control. Upon removing the internal calibration reference, the meter is again set for a zero scale setting by using the zero adjust control. Normally, the entire calibration procedure is repeated.

The electronics system of this densitometer allows for a rapid warmup; however, you should wait 30 minutes to permit other optical components, such as filters, to reach thermal equilibrium. Because this densitometer is manually operated and calibrated, both the zero adjust and calibration control settings should be checked several times during the day. Run through the entire operating procedure to reset the densitometer whenever necessary to insure that the instrument is performing according to the factory specifications.

Changing aperture disks. After following the operating instructions, you proceed to measure the density of film samples. These density measurements are for the 2-mm diameter aperture disk, normally installed in the densitometer. This aperture disk can be replaced by either the 1-mm or the 3-mm aperture. You must first remove the circular stage diffuser and push out the 2-mm diameter aperture disk. The aperture disks are made of aluminum and are fitted with neutral density filters. Therefore, care must be taken when making such replacements. Use a rod of soft material, such as wood or plastic, to push the aperture disks out of the circular stage diffuser to avoid damaging the aperture.

When operating the instrument with the 1-mm aperture, the light source intensity must be changed. To do this, you remove the base cover plate and move the light source wire from the 6-volt terminal over to the 7.3-volt terminal on the terminal strip of the power transformer T1.

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NOTE: If, after changing the light source intensity, you cannot zero the meter with the zero adjust control, follow these procedures:

(1) Rotate the filter selector knob through all four positions and note which filter position gives the highest density reading.

(2) Remove the filter turret from the photomultiplier housing.

(3) Remove the necessary amount of filter trim from the filter position for which the highest density reading was obtained.

(4) Replace the filter turret in the photomultiplier housing.

(5) Follow the zero adjust and filter trim procedures described in the operating instructions.

Calibration reference control. To assure that your Quantalog TD–102 densitometer performs to the high precision required, a calibrated "standard" step tablet is included with each instrument. To limit the use and resultant wear of this standard step tablet, a calibration reference control is built into the instrument. This control is an easily inserted "working standard" and has two basic uses.

- It eliminates the continuous use of the standard wedge.
- It provides an easily inserted calibration reference point.

To maintain the accuracy of the working standard (calibration reference), it should be checked once each week against the standard wedge.

Assign the working standard (calibration reference) value as follows:

(1) Allow the instrument to warm up for one hour.

(2) With the proper aperture in place, turn to the visual filter position and adjust the instrument according to the operation instructions.

(3) Set up the calibration by using step 14 of a standard wedge.

(4) Check zero and step 14 again to insure that the controls are properly adjusted.

(5) Remove the step wedge, depress the snout lever, and move the "calibration reference" backward until it clicks in.

(6) Note and record the reading, using a plus reading if necessary (for instance, 2.81+) or, conversely, a minus reading on one of the pressure-sensitive tags supplied with the instrument.

(7) Once each week, check the working standard and reassign the value of the "calibration reference" if necessary. Spare tags are provided for this purpose.

Maintenance. The maintenance of black-and-white densitometers can be split into two general classifications: (1) optical maintenance and (2) electrical maintenance. The null-type visual instrument, having few critical adjustments, requires very little maintenance, and all of it is of an optical nature. This type of densitometer is considered first in terms of symptoms, causes, and remedies, which are shown in table 1-1.

Maintenance of direct-reading photoelectric instruments is more involved because of the greater complexity of such instruments. They require both optical and electrical maintenance, as shown in tables 1-2 and 1-3.

Techniques for cleaning and adjusting optics have not been discussed, since they are considered to be within the scope of routine shop maintenance. Also, because of the many different instruments in use, only the generalities of electrical maintenance have been indicated. However, electrical maintenance of these instruments should be performed by a qualified 404X0, Precision Photographic Systems Repairman.

Central calibration facility. As with sensitometers, densitometers also fall within the AFCCF program. The densitometer calibration kits are produced by the Precision Measurement Equipment (PME) Section at Hill AFB. They consist of a step tablet calibrated using a PME standard densitometer. The density values of the step tablet are recorded on AFTO Form 249, PME Calibration Data, and packaged with the step tablet.

Exercises (807):

1. How can you establish a control on a densitometer? Explain.

2. How is the precision control level indicated on a chart, and how is it used?

3. On a densitometer used to measure transmission densities, what are the advantages of using a linear scale to obtain density values?

4. In order to adjust the needle of the meter on the Quantalog densitometer to a specific scale density, for which the instrument was calibrated, which of the controls must be adjusted?

5. To ensure that the instrument is performing according to factory specifications, what operating procedures should you follow?

6. To assure that the Quantalog TD–102 densitometer performs to its expected precision, what kind of a calibration reference control is included with each instrument?

TABLE 1-1

MAINTENANCE OF NULL-TYPE VISUAL DENSITOMETERS

Symptom	Cause	Cure
(1) Density readings too high (particularly at higher end of scale)	(a) Attenuator deteriorating (b) Optics dirty, causing scattered light (c) Geometry becoming more specular	(a) Replace (b) Clean
(2) Density readings too low (particularly at higher end of scale)	(a) Attenuator deteriorating (b) Geometry becoming more diffuse (if instrument is not a completely diffuse instrument)	(a) Replace (b) Adjust
(3) Poor precision of density readings	(a) Low lamp output, making visual matching difficult	(a) Replace lamp

TABLE 1-2

OPTICAL MAINTENANCE OF DIRECT-READING PHOTOELECTRIC DENSITOMETERS

Symptom	Optical Cause	Cure
(1) Density readings too high (particularly at higher end of scale)	(a) Optics dirty, causing scattered light (b) Geometry becoming more specular	(a) Clean (b) Adjust
(2) Density readings toó low (particularly at higher end of scale)	(a) Geometry becoming more diffuse (if instrument is not a completely diffuse instrument)	(a) Adjust
(3) Poor precision of density readings	(a) Fluctuations of line voltage, causing changes in lamp output (b) Low lamp output	(a) Control line voltage (b) Replace lamp

TABLE 1-3

ELECTRICAL MAINTENANCE OF DIRECT-READING PHOTOELECTRIC DENSITOMETERS

Symptom	Electrical or Electronic Cause	Cure
(1) Density readings too high (particularly at higher end of scale)	(a) Amplifier nonlinear	(a) Replace faulty tubes or faulty bandpass filter
	(b) Phototube nonlinear	(b) Replace phototube
(4) Density readings too low (particularly at higher end of scale)	(a) Amplifier nonlinear	(a) Replace faulty tubes or bandpass filter
	(b) Phototube nonlinear	(b) Replace phototube
	(c) Noise in instrument	(c) Replace faulty phototube, amplifier tube, resistor or capacitor (Noise may be localized by tapping various components while a high density sample is in the beam.)
	(d) Noise in signal cables between units of instrument	(d) Replace faulty cables
(3) Poor precision of density readings	(a) Density meter sticking	(a) Replace meter
	(b) Poor servo action on recorder	(b) Adjust servo
	(c) Noise in instrument	(c) Replace faulty phototube, amplifier tube, resistor or capacitor
	(d) Noise in signal cables between units of instrument	(d) Replace faulty cables
	(e) Variation in speed of light interrupter	(e) Repair or replace

7. When the output of a null-type densitometer is low, what is the effect and what is the remedy?

1-3. The Sensitometric Curve

In order to analyze and understand the results of a sensitometric test, you must plot the density of each step in a test strip in relation to the exposure which was required to produce that density. A characteristic curve is then constructed on graph paper by plotting the densities of the exposed and processed strip against the logarithms of their corresponding exposures. This principle was originated by Hurter and Driffield and is called an H and D curve in their honor. You may also find the characteristic curve referred to as a D log H curve or a sensitometric curve.

808. State how you arrive at data for plotting a characteristic curve.

Plotting a Characteristic Curve. When the values of density (as measured in a test strip) are placed in a column

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beside the exposures that produced them, the two columns would represent the relationship between exposures and densities for that particular emulsion. The box above the curve in figure 1-7 shows how the completed table would appear. Because the relationship between exposure and density may be hard to visualize from a table of this sort, it is much better to use a graphic representation, such as the curve shown in figure 1-7.

In this graph, the density (log O) is plotted against the logarithm of the exposure (log H). Note that the exposures and densities are plotted in geometric progression by powers of 10 or in a logarithmic progression.

Density vs. density curves. Figure 1-8 shows how a test strip that has been printed through a standard step tablet would be plotted. This tablet consists of 21 steps, ranging in density from approximately 0.05 to approximately 3.05. There is a density difference between each step of 0.15. The recommended procedure for plotting a curve, based on results from a test made in this manner, is as follows:

a. The densities of the original step tablets are read and recorded.

b. The densities obtained in the test strip are read and recorded in a column beside the densities of the original, such as was done in figure 1-9.

c. A graph sheet having 20 squares to the inch is marked off in periods of 0.20 density units to the half inch, starting with zero in the lower right-hand corner and moving to the left along the baseline (horizontal axis) and upward along the right side (vertical axis).

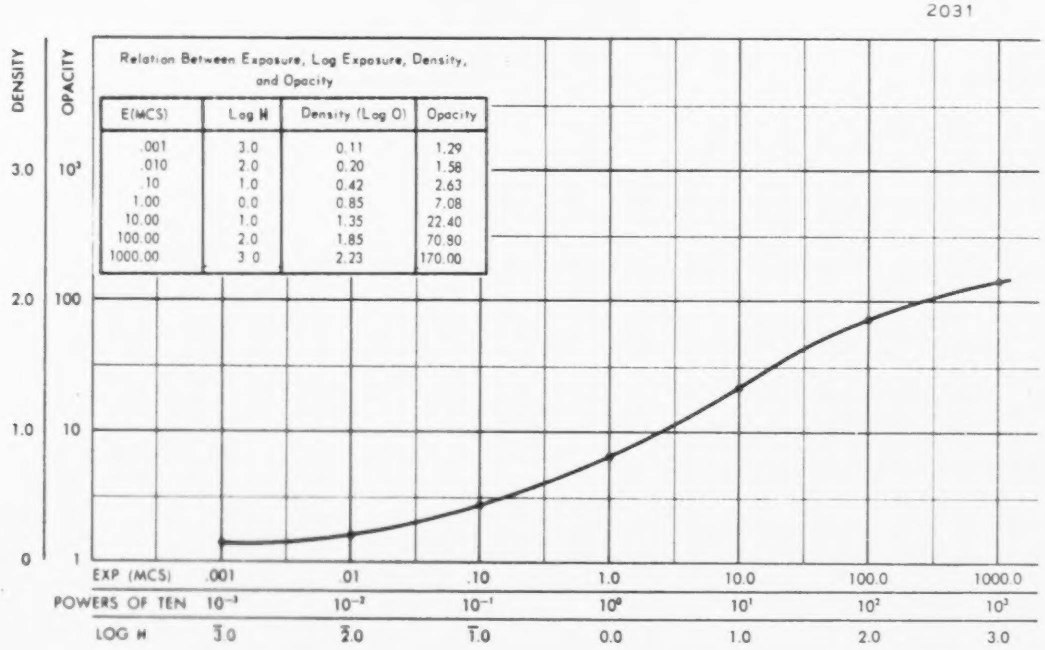
d. The densities of the original step tablet are then plotted across the baseline, with step 1 located near the right end and step 21 located near the left end of the line.

e. The density of each step of the test is then plotted by placing a dot on the graph opposite its value on the vertical axis and above its axis. This is continued until all 21 steps are plotted.

f. The dots are then connected with a "best fit" curve, using a straight edge and French curve, and the result will be a characteristic H and D curve in relative D log H values.

Curve construction. To construct a D log H curve, it is necessary to determine the log exposures that produced the densities in the strips to be plotted. From previous experience, you know that exposure is the product of illumination multiplied by time. This fact means that the log H can be readily computed simply by finding the log of the illumination and the log of the time and adding them. Manufacturers of sensitometers supply all pertinent data which can usually be applied directly. However, you can calculate the log exposure range of a sensitometer by first measuring the output of the light source in meter-candles, then finding the logarithm (to the base of 10) of the light value and adding it to the logarithm of the exposure time in seconds. Or the value of the intensity of the light in meter-candles can be multiplied by the time of exposure in seconds and the logarithm of the product found.

When you use filters in the system, their density values are merely subtracted from the log exposure to give the new log exposure. In time-scale sensitometers, the time-intensity value must be calculated for each step. But in intensity-scale instruments, the constant log exposure is attenuated by the density of each step in the step wedge, and the log H for each step can be found by subtracting the density of each step from the log exposure of the sensitometer.



Relation Between Exposure, Log Exposure, Density, and Opacity

E(MCS)	Log H	Density (Log O)	Opacity
.001	3.0	0.11	1.29
.010	2.0	0.20	1.58
.10	1.0	0.42	2.63
1.00	0.0	0.85	7.08
10.00	1.0	1.35	22.40
100.00	2.0	1.85	70.90
1000.00	3.0	2.23	170.00

Figure 1-7. Graphic representation of ratios between exposure and densities.

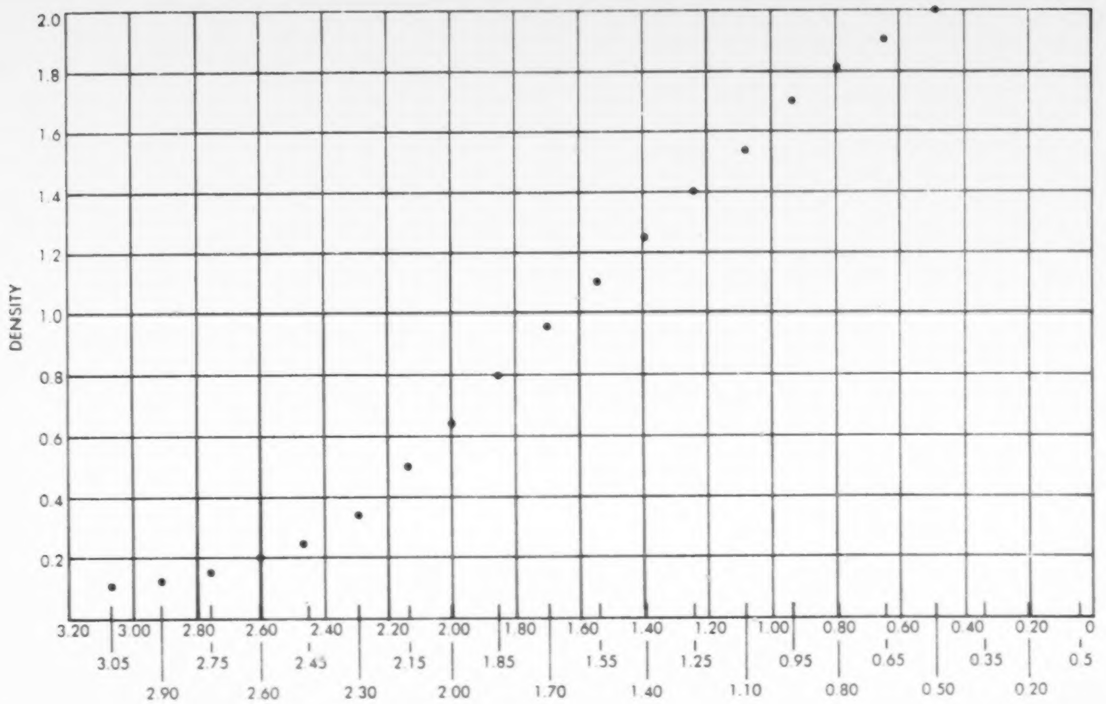


Figure 1–8. Plotting densities.

Quite often, instead of reading the densities of each step of the exposure modulator wedge, you might read just the minimum density steps (to obtain the maximum log H) and assume density increments of 0.15 for a 21-step wedge, or increments of 0.30 for an 11-step wedge. The values you obtain in this manner may not be the exact ones in the wedge, but the error may be not greater than operator and experimental errors that occur when the steps are read on densitometers. Bear in mind that while this method may be satisfactory in some instances, it may not be in others. When you have exacting requirements, you must use precise methods.

For curve plotting, you will find it convenient to use a sheet of graph paper that is ruled 20 units to the inch (20 x 20 per inch) or 10 units to the half inch (10 x 10 per 1/2 inch). Mark off the baseline in even increments of 0.20 log H units to the half inch. Be sure that you provide enough space to accommodate the range of log H's for the 21 steps used to produce the strip being plotted. (By placing the 0.0 point on a line 2 inches from the right edge, you can usually provide sufficient space.) Considering the baseline as zero, now mark off the vertical axis in increments of 0.20 density units per half inch.

The log H's of the 21 steps are then plotted along the horizontal axis, and the corresponding densities of the test are plotted in their proper positions above them, in the manner illustrated in figure 1-10.

Since all H and D curves are similar in appearance, every graph should be labeled with all pertinent information. Information that is not set down on the graph can be misplaced or forgotten and makes the graph useless. The following items should be shown on the graph:

- The vertical (density) axis.
- The horizontal (log H or original density) axis.
- The kind of material being tested.
- The developer and development used.
- The gamma obtained.

The D log H curve is a graphic representation of the effects of exposure and development. As you probably know, changes in either will cause the curves to shift. Any increase of the exposure moves the curve to the left, whereas a decrease of the exposure moves it to the right. Increasing development causes the slope of the curve to become steeper, while decreasing development makes it flatter.

Because the curve represents a continuous condition, you can readily locate any intermediate density and its corresponding log exposure. You are not confined to the steps of the wedge. As you continue your study of D log H curves, you will increase your ability to interpret them. To that end, the following paragraphs take you deeper into an analysis of curves.

Step Nr.	Density of Original	Density of Test
1	.05	2.15
2	.20	2.12
3	.35	2.06
4	.50	2.00
5	.65	1.92
6	.80	1.82
7	.95	1.70
8	1.10	1.55
9	1.25	1.40
10	1.40	1.25
11	1.55	1.10
12	1.70	.95
13	1.85	.80
14	2.00	.65
15	2.15	.50
16	2.30	.37
17	2.45	.27
18	2.60	.20
19	2.75	.15
20	2.90	.13
21	3.05	.10

Figure 1-9. Density comparisons.

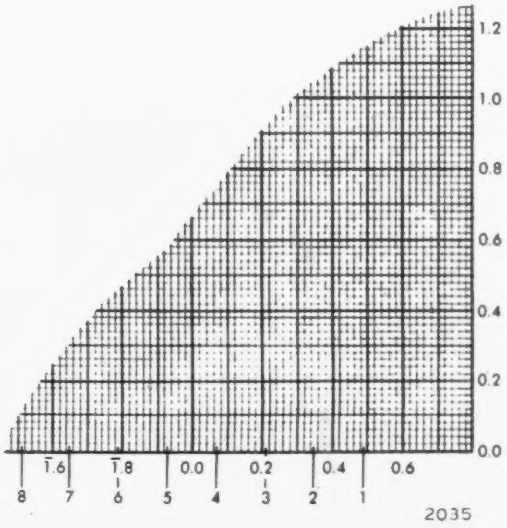


Figure 1-10. Marking log H values.

Exercises (808):

1. How may you graphically analyze a sensitometric test?

2. Give the ways in which the original measurement of a light source is converted to data for plotting an H and D curve.

3. Compare the customary logarithm difference used between each step: (1) in a step wedge with the full range of densities, 21 steps, with the customary logarithmic difference used between each step; and (2) in an 11-step wedge.

4. What the information usually is shown on every H and D curve graph?

809. Tell how to interpret sensitometric curves and state the meanings of the parts of sensitometric curves.

Interpreting Sensitometric Curves. Through your knowledge of sensitometry, you can measure, record, and graphically represent the reaction of photosensitive emulsions to varying conditions of exposure and development, and you can analyze and interpret the results. Through sensitometric measurement, not only can you determine the effective film speed, latitude, and useful exposure range of emulsions, but you can also exercise constant control. Virtually all sensitometric determinations include the analysis of D log H curve as part of the procedure.

Structure of the curve. For recall purposes, study figure 1-11, which illustrates a graph of a hypothetical curve with all of its essential parts identified. Note that the graph itself provides two axes so that density vs. log H plots can be located. The horizontal axis, or abscissa, is the log H axis; and the vertical axis, or ordinate, is the density axis. The graph should be long enough to permit an exposure range equal to or greater than the range of exposures produced by the sensitometer and should be deep enough to accommodate a complete range of densities.

The lower portion, or toe, of the curve is the region of increasing gradient, where increases in density are greater than proportional to their corresponding exposure increases. The straight-line portion is the region of constant gradient, where density increases are proportional to their corresponding exposure increases. The upper portion, or shoulder, is the region of decreasing gradient, where density increases are less than proportional to their corresponding increases in exposure.

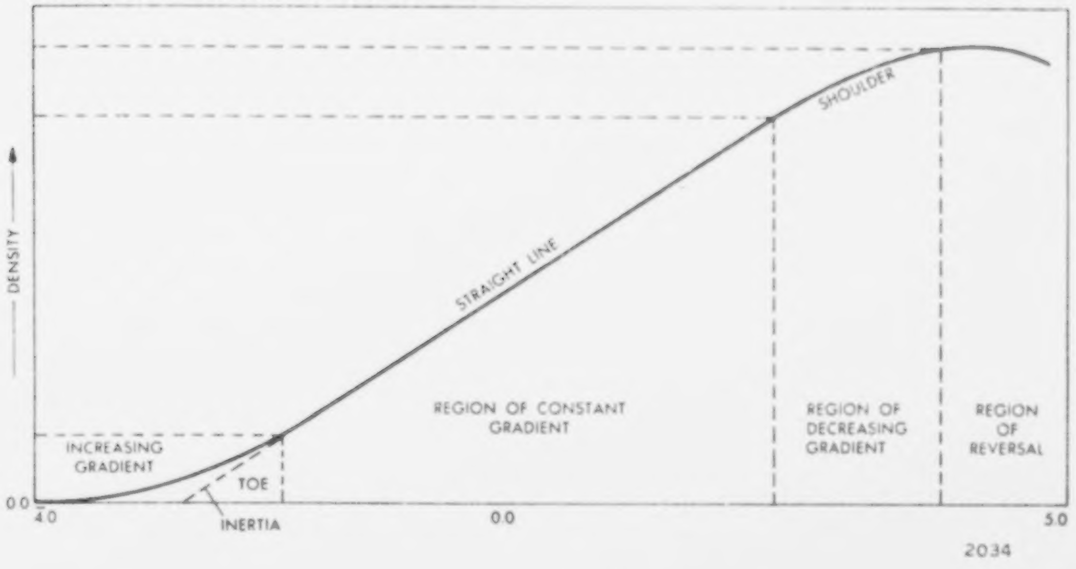


Figure 1-11. Components of a typical D log H curve.

As the exposure continues to increase, the density values decrease even more, until the curve enters what is known as the region of reversal. In actual practice, however, most of your exposures lie along the toe and straight-line gradients. You will seldom have an exposure that produces densities up to the shoulder, and probably never in the reversal region. Extremely long exposures are needed in order to produce the reversal effect.

Figure 1-12 illustrates the characteristic curve of a typical panchromatic emulsion. First, notice that the curve is placed on the graph so that some density above zero is shown as the least density. This portion of the curve represents the density of the base-plus-fog level of the film. Notice also that the curve has a well-defined toe, a long straight-line gradient, and a slight shoulder.

The toe is flat at its extreme end, representing the base-plus-fog density of the emulsion. The length of this flat portion of the toe is affected by the amount of overall exposure the film has received. When the exposure is low, the flat portion of the toe is longer and the straight-line portion is moved to the right, as shown in figure 1-13,A. On the other hand, increasing the exposure shortens the flat portion of the toe and moves the straight-line portion to the left, as you see illustrated in figure 1-13,B.

A flat toe indicates that silver halides have not been exposed long enough to render them developable under the developing conditions used in the test. It is possible that using a more energetic developer or, perhaps, increasing developing time may shorten the flat part of the toe. However, both actions also produce a steepened straight-line gradient but do not appreciably change the extreme end of the toe (fig. 1-13,C). While shortening the development time to compensate for overexposure may produce a toe, this action also produces a flatter curve, as shown in figure 1-13,D.

The threshold is the point on the toe of the curve where the density first becomes perceptible. This point is variable, because no two observers see exactly alike and therefore may disagree as to where threshold density actually starts. This is why some procedures for calculating film speed (including ASA) set a specific density above base fog as a basis for measurement.

On the straight-line gradient, equal changes in log H produce equal (or almost equal) changes in density. Any deviations from a straight line occurring in normally exposed and developed sensitometric strips will average out and, for all practicable purposes, can be ignored in most calculations. Since values along this portion of the curve are linear and have density differences which change proportionally with the log H, you can select an exposure for any desired density (on the straight line) or you can predict a density for any preselected exposure.

Normally, the shoulder of a characteristic curve is somewhat convex. The density changes represented by it are less than corresponding log H changes. Although density is still increasing, the increase would not be as rapid as along the straight line or the toe. It continues to increase until maximum density (D_{max}) is reached. If the exposure continues to increase beyond this point, the reversal effect is produced. Most camera exposures avoid the shoulder. In this area, detail is lost because the density differences are not great enough to allow the viewer to distinguish between them, and the result is blocked-up highlights.

Log H axis. If you photograph a uniformly lighted gray card, the camera exposure can be represented as a single point somewhere on the log H axis. If you increase the light

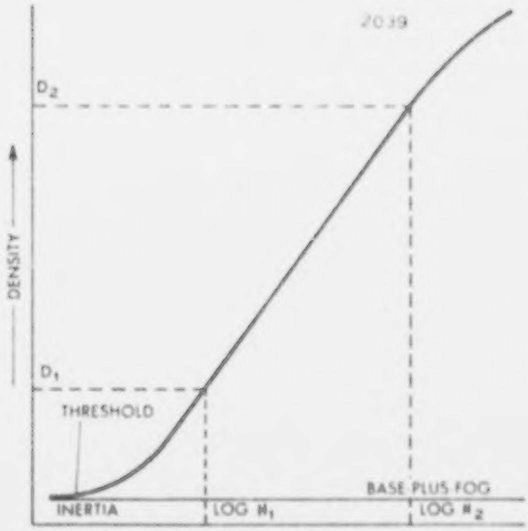


Figure 1-12. D Log H characteristic curve (panchromatic emulsion).

and make a second photograph, using the same camera settings, this exposure can also be plotted as a point on the log H axis. This second point will, however, be plotted to the right of the first point. The distance separating the two points will depend upon how much more light is used for the second exposure. When you place a second card having a different reflectance beside the first and photograph the two together, the exposure can be represented as two points on the log H axis. Again, the separation between them will depend upon the ratio of light intensities reflected by the two cards.

Increasing the exposure (for instance, by slowing the shutter or opening the aperture) will move both points to the right but will not change the distance between them. Decreasing the camera exposure will, of course, move the points to the left on the log H axis. This is an oversimplified description of what takes place whenever the number of camera exposures produced is equal to the number of different luminance levels in the scene. Each can be represented by some point on the log H axis, and changes in the camera setting shift all points either to the right or to the left.

Density axis. When you process the third exposure made of the two cards mentioned above, two densities will result

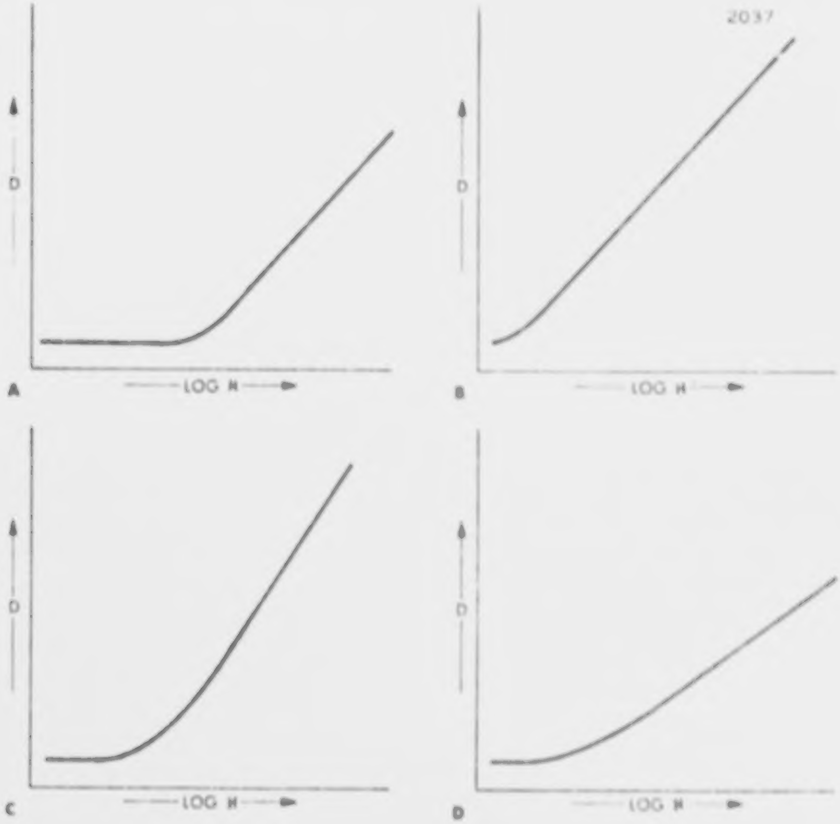


Figure 1-13. Effects of exposure and development on a characteristic curve.

and these can also be plotted on the graph. Each density will occupy a position directly above its corresponding log exposure. The plot on the right (having received the greater exposure) will be higher than the one on the left. In this manner, the densities produced by all of the brightnesses of a scene (if you could measure them) could be plotted. These points could be connected by a smooth curve having a toe, a straight-line portion, and a shoulder.

The degree of development given is reflected by the shape of the curve and the slope of the straight-line portion. An increase in development causes the straight-line portion to become steeper and increases the difference between the densities lying upon it and in the toe. The base-fog level and the areas of minimum density are affected very little by increases in development, and the changes in the toe shape are largely the result of the straight line becoming steeper. Figure 1-14 illustrates how, with increasing development, the straight line continues to steepen until a point is reached where additional development no longer causes an increase in the gradient. This point is referred to as "gamma infinity" and is discussed in more detail later in this text.

Gamma. The numerical description of the effect of development upon the characteristic curve is designated by the Greek letter gamma (γ). It is frequently defined as the ratio of the difference between any two densities on the straight-line portion of the curve and the difference between their corresponding log exposures, and it is shown by the equation

$$\gamma = \frac{\Delta D}{\Delta \log H}$$

Where Δ D is the interval between straight-line densities, and Δ log H is the interval between the log exposures producing these densities. These interval values are shown in figure 1-15.

The above equation is an expression of the average slope or gradient (G) for the interval Δ log H. However, the gradient of any characteristic curve, except for its straight-line portion, is not constant and, therefore, the equation can be modified and expressed in the following form:

$$G = \frac{dD}{d \log H}$$

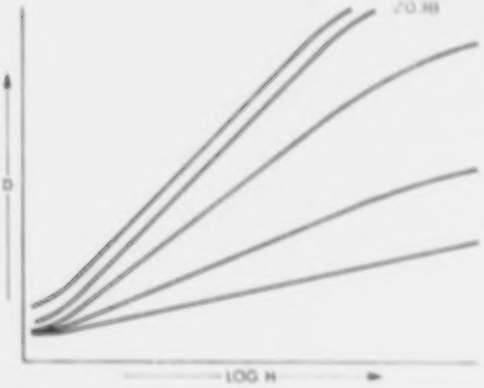


Figure 1-14. Gamma infinity.

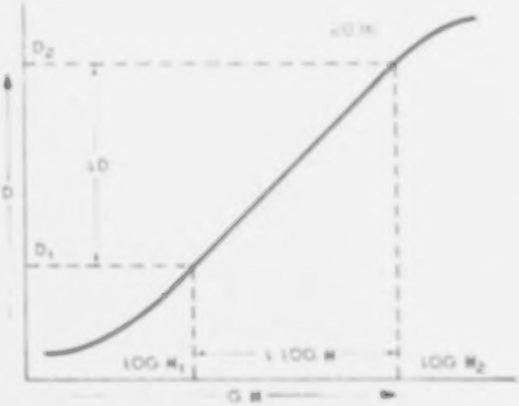


Figure 1-15. Deviation of ΔD and Δ log H.

However, the constant gradient of the straight-line portion can also be stated as the tangent of the angle occurring between the straight-line portion of the curve and the log H axis (fig. 1-16).

The tangent of this angle was designated by Hurter and Driffield as gamma (γ). Therefore, the straight-line portion is:

$$G = \frac{\Delta D}{\Delta \log H} = \text{constant} = \tan \alpha = \gamma$$

So it is that γ is the proportionality factor characterising the relation between (*D log H and corresponding Δ D.

As an example, let us assume that two areas in an object being photographed have brightnesses of 10 units and 80 units. The Δ D log H value of this object would be log 80—log 10, or 0.90. Let us assume further that the densities produced by these areas both are located on the straight-line portion of the curve and that the γ = 0.8. Then,

$$\frac{\Delta D}{0.90} = 0.8$$

Therefore,

$$\Delta D = 0.90 \times 0.8 = 0.72$$

When a = 45°, tan a or γ becomes (1.0). Consequently, any log H increment is rendered in the negative by an identical density difference. If γ is less than unity, the proportional reproduction will be correct, but the object brightness scale will be compressed; and if γ is greater than unity, correct proportional reproduction will also be obtained, but the brightness scale will be expanded.

If the straight line is extended until it intersects with the zero density log H axis, as shown in figure 1-17, gamma can be found by counting off 100 log H increments to the right and running a perpendicular line to intersect with the straight-line gradient of the curve. Gamma is equal to the density value at this point. Probably the simplest way to find the gamma of a characteristic curve is to use a gamma meter, which is illustrated in figure 1-18. The gamma meter

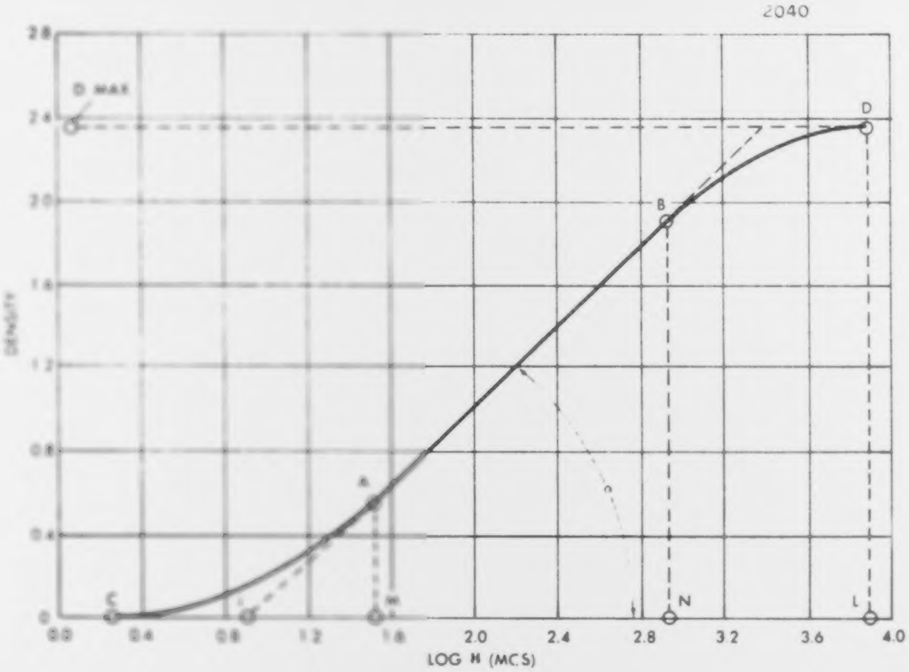


Figure 1-16. Gamma (γ).

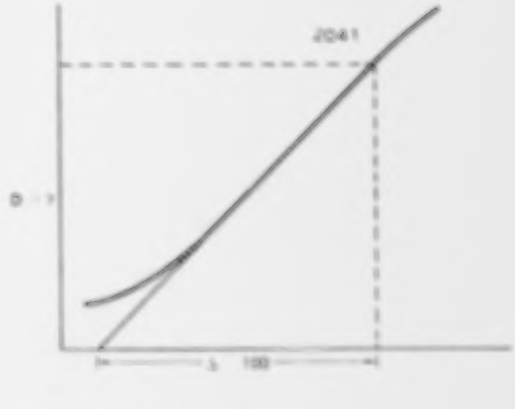


Figure 1-17. Determining gamma graphically.

is placed on the curve so that the baseline is parallel with the log H axis, and the arrowpoint touches the straight line at some point above the toe. Gamma is read where the perpendicular intersects the straight-line portion of the curve.

Significance of gamma. Gamma is often referred to as development contrast, but this is not an accurate description. Since gamma is concerned solely with the straight-line portion of the curve, it can only indicate the contrast of that portion. It is a useful measure of degree of development and, as such, is a valuable processing control. An increase in gamma indicates an increase in development, all other parameters being unchanged. An increase in time, temperature, agitation, or developer activity results in increased gamma, and a decrease in any of these factors results in decreased gamma. A moderately energetic developer can produce high gamma if the time, temperature, or both, are increased. Moreover, the reverse is true: A high-energy developer can be made to produce low gamma if the other factors are held back.

It is important to remember that gamma relates only to development and not to exposure. A camera negative developed to a predetermined gamma will process to that gamma regardless of the exposure. The densities in the negative which correspond to straight-line densities in the D log H curve will have the same density differences. Of course, sensitometric curves resulting from different exposures occupy corresponding different positions on a graph.

Exercises (809):

1. Give the determinations which can be established through sensitometric measurements.

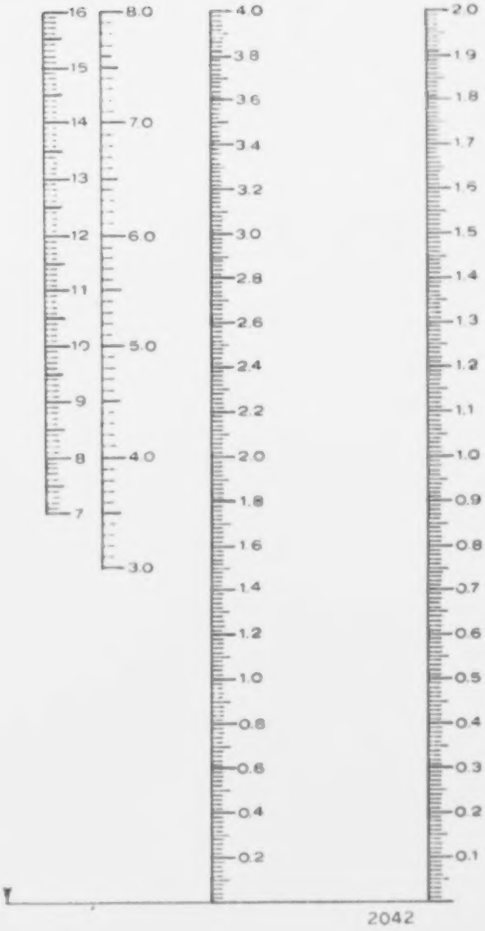

16
15
14
13
12
11
10
9
8
7
8.0
7.0
6.0
5.0
4.0
3.0
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2042

Figure 1-18. A gamma meter.

2. What is the relationship between exposure and density in the region of reversal of a characteristic curve?

3. When exposure is lessened, what effect will this have on the H and D curve and its toe?

4. Although subjective, at what point on a characteristic curve does a negative first become visible?

5. In analyzing an H and D curve, what two deductions can you make from the straight-line portion?

6. What does the amount of space between two points along the log H axis of a curve rely on even though the camera settings remain the same?

7. Referring to exercise 6, if only the exposure were decreased, what effect would the decreased exposure have on the second set of the two points?

8. An improved version of the equation $\gamma = \frac{\Delta D}{\Delta \log H}$ is used to determine what other properties of the straight-line portion of an H and D curve?

9. Which of the two—H and D curve or its straight-line portion—is more descriptive of the term "development contrast"? Why?

10. Of what significance is the fact that the tan γ is greater than or less than 1?

11. How can a flat toe of an H and D curve be interpreted?

CHAPTER 2

Sensitometric Control

SENSITOMETRIC control in a processing facility is based on the results obtained when comparing different developing solutions, their composition, and time-temperature relationships. To these results must be added those obtained from a study of various film characteristics. Of particular interest when studying these characteristics are the relationships between time, gamma, and base fog. The level of base fog, inherent in all films to various degrees, is important; first, because it can decrease the amount of information that can be extracted from an exposed negative. Secondly, control film stock, used for sensitometric exposures, must be closely watched, since both heat and time have an influence on base fog.

Equally important are the results obtained from exhaustive exposure tests in which the amount of latitude, contrast, and speed of various films are determined. What is being tested here is the sensitivity of photographic emulsions to visible light or other radiations. We say other radiations because an infrared film emulsion can record details whose shape and texture are reflecting radiations which cannot be seen by the human eye. Emulsions of photographic printing papers are also affected by visible light and the characteristics of the printing papers. Because of its peculiar construction, sensitometric values of printing papers must be determined through the amount of reflected light rather than the amount of light transmitted as with negative materials. These values are important because they are useful in determining paper contrast grade and the methods of changing the contrast index—if this becomes necessary.

The use of tone reproduction control has enabled many imagery production facilities to obtain the maximum amount of recorded information from each negative of a valuable reconnaissance mission. By understanding various parameters of tone control, an imagery production technician can predict the photographic result of almost any roll of mission negatives. To do this, he or she consider camera image flare, atmospheric haze, and negative and positive characteristic curves; their effect upon the tone reproduction curve shows whether one or more generations of printing (and subsequent processing) from the original negatives are necessary to obtain the maximum detail sought by a photographic interpreter.

2-1. Exposure Control

In some photographic applications, it is advisable to confine exposures to the straight-line region of the curve. However, there are good reasons why it is frequently advisable to use exposures beginning somewhere on the toe. For example, the rate at which the density differences increase is greater in the toe than anywhere else on the curve; and with the proper printing exposure, the shadow details are quite apparent. Also, a range of scene luminances, with the minimum brightness recorded on the toe rather than on the straight line, produces a negative whose overall density is low.

In the laboratory, negatives with low overall density permit you to operate with a shorter printing time. In addition, placing the minimum exposure on the toe increases the exposure latitude (in the direction of increased exposure) over that available on the straight-line gradient. This practice is so prevalent that, instead of gamma, many photographic technicians favor using the numerical value of some average gradient originating on the toe. This is particularly true when contrast is the prime consideration. This is an additional tool and does not replace the very useful gamma. Contrast index, as the new value is sometimes called, is employed mainly in sensitometric analysis of subject luminances and exposure, whereas gamma is used chiefly in process control, evaluation of density differences, and tone reproduction control.

810. State the importance of the latitude value of a characteristic curve.

Latitude. If you refer to figure 1-16, you will note that points M and N on the log H axis correspond to the limits of the straight-line portion, and the distance between these points is known as *latitude*. Latitude can be expressed either in log H units or in exposure units, shown thus:

$$\text{Latitude} = \log \text{Hn} - \log \text{Hm} \ (\log \text{H units})$$

or

$$\text{Latitude} = \text{Hn}/\text{Hm} \ (\text{exposure units})$$

The latitude value of given D log H curve determines the maximum object contrast (ratio of maximum to minimum object luminance) which may be proportionally rendered between density and log exposure on a specific photographic material, processed under specific conditions. Latitude is not constant for a given photographic material, since it depends primarily upon the degree of development given and, to some extent, upon the spectral composition of the radiation to which the material was exposed.

Exercises (810):

1. Of what importance is the latitude value of a specific characteristic curve?

811. Explain how a contrast index is determined and name the tool which will help speed up your determination.

Contrast Index. Because γ is equal to the ratio of the negative density difference to the corresponding exposure difference, it is used by many persons to express the contrast of a photographic material. But we should never forget that γ describes only the straight-line portion of the curve and gives no information concerning the contrast characteristics of other parts of the D log H curve.

Since γ cannot describe contrast when portions other than the straight line of the curve are used, some research scientists have suggested an alternate basis for describing contrast. Reasoning that a density of 0.10 above base-plus-fog density can be a useful threshold density, that point on the D log H curve was selected as a starting point. Then, assuming that a log H range (Δ log H) of 2.00 will provide a suitable range of tones, it was selected as a limiting gradient point. A value equal to the tangent of an imaginary line drawn between these two points is determined and known as contrast index.

Figure 2-1 illustrates graphically how the contrast index value is determined. Point A is 0.10 above base-plus-fog, and point B is separated from it by 2.0 log H increments. Contrast index (C.I.) is derived by the equation:

$$\text{C.I.} = \tan\alpha$$

By using a nomograph similar to the one shown in figure 2-2, this relationship can be determined quickly. The nomograph is used in the same manner as a gamma meter except that the arrow is placed on the point in the D log H curve, which is equal to 0.1 above base-plus-fog; and with the proper vertical and horizontal orientation, the C.I. value is read where the arc intersects the straight-line portion of the curve.

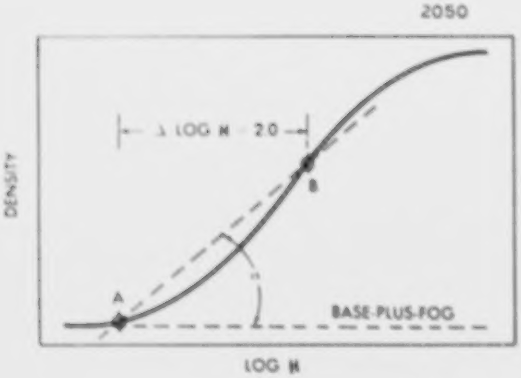


Figure 2-1. Limiting gradient of D log H curve.

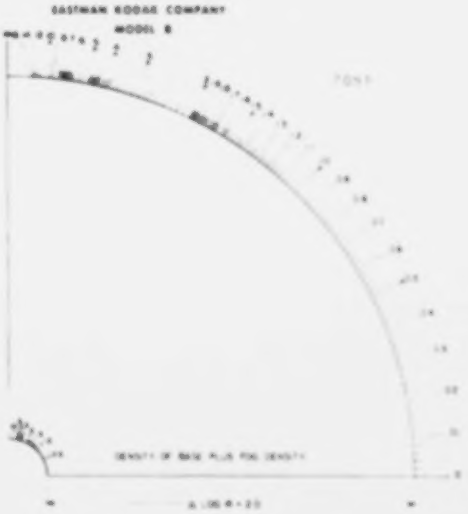


Figure 2-2. Contrast nomograph.

Exercises (811):

1. How is a typical contrast index value determined?

2. What tool is available to help you expedite the determination of contrast index?

2-2. Film Speed

Speed, as it is applied to photographic emulsions, indicates a measure of the emulsion's sensitivity to an exposing radiation. By definition, it is the reciprocal of the exposure needed to produce a desired result. There have been many approaches to the problem of rating film sensitivity, the more important of which are described briefly in the following paragraphs.

812. List and explain the methods for determining film speeds, and tell what film speeds indicate.

Federal Specification Speeds. Federal Specification L-F-330 lists several methods for determining film speeds as follows:

Method A is defined as

$$\text{speed} = \frac{1}{H}$$

where H = exposure in meter-candle seconds at point of tangency on D log H curve of slope 0.30 of average limiting gradient of 1.5 log H units.

This is the speed point of the L. A. Jones (Old ASA) without the safety factor.

Method B speed is for rating aerial film and is stated as

$$\text{speed} = \frac{0.5}{H}$$

where H = exposure in meter-candle seconds at the point of D log H where tangent slope is 0.5 of the measured gamma.

This method is variously known as *USAF Maximum Shadow Detail Speed* and half-gamma speed.

Method C speed, for use with motion picture positive film, is

$$\text{speed} = \frac{10}{H}$$

where H = meter-candle seconds exposure at point of D log H where density is 0.30 above base-plus-fog density.

Method D, used with reversal film, is stated

$$\text{speed} = \frac{10}{H}$$

where H = exposure in meter-candle seconds at point of D log H toe where instantaneous slope is 0.60.

Method E, for photomechanical and process films, is defined as

$$\text{speed} = \frac{10}{H}$$

where H = exposure in meter-candle seconds at D log H point where density is 0.60 above base-plus-fog density.

Method F, for transparency film speed, is stated as

$$\text{speed} = \frac{1000}{H}$$

where H = exposure in meter-candle seconds at D log H point where density is 1.20 above base-plus-fog density.

Aerial film speeds. Because the characteristics of aerial scenes are so different from those of conventional photography, the film speed rating system for aerial photography must also differ. For this reason, the Aerial Exposure Index (AEI) system was developed to be used in place of the ASA speed values. It was the best answer that the users and manufacturers, working together, could devise at that time. The AEI was phased out by manufacturers and the Air Force users and was replaced by Aerial Film Speed (AFS) for determining effective film speed.

Method B film speed of Federal Standard L–F–330 is specified for aerial film speed and is also known as the half-gamma speed or USAF Maximum Shadow Detail Speed. In military aerial reconnaissance, it is well known that much more significant intelligence data is contained in the shadow areas of the photograph than in the other areas. For this reason, it is customary to expose aerial reconnaissance films for the shadows.

Both the half-gamma and AEI speed points will fall on the toe of the curve at a level above base-plus-fog density where significant detail can be recorded. Any increase in exposure will produce density differences great enough to record useful image detail.

Since both of these speeds are highly dependent on the gamma of the film, the speed can be varied by varying the gamma. As gamma increases, the speed point moves right and, as gamma decreases, the speed point moves left.

In the past, most emulsion manufacturers, camera manufacturers, sensor maintenance personnel, and processing labs used half-gamma speed or AEI speed criterion for original films. Therefore, you should know how to compute these speeds. The method is as follows:

(1) Measure gamma. Multiply by 0.5 for half-gamma or by 0.6 for AEI.

(2) Determine the point where this gradient is tangent to the toe of the curve.

(3) Determine the log H value at this point.

(4) The speed in either method is defined as 1/2 H. Find the antilog of the log H and multiply by two; find the reciprocal of this value. A simpler method of calculation is to add 0.301 to the log H value, subtract the result from zero, and find the antilog of the final result which gives the speed value. (NOTE: The American National Standards Institute has adopted a standard for aerial film speed: ANSI Standard PH 2. 34–1969, *A Method of Determining the Speeds for Monochrome Photographic Negative Films for Aerial Photography*.)

Aerial film speed for black-and-white negative aerial films is defined as 3/2 H, where H is the exposure (in meter-candle seconds) at the point on the toe of the curve where the density is 0.30 above base-plus-fog density. The processing conditions, such as time, temperature, agitation, and developer, are strictly defined in ANSI Standard PH 2.34–1969.

Effective aerial film speed is the term prescribed by the standard for films processed under conditions other than that specified in the standard. Although different processing conditions may be used, the basic speed criterion for black-and-white aerial films is still the same. The processing conditions must be specified along with the effective aerial film speed (EAFS) value reported. When the procedures are accomplished within the organization itself and the film speed value is the product of the production variables of that organization's system, the film speed value is known as the effective aerial film speed (EAFS). While a given film might be rated at 32 AFS by the manufacturer, a field organization's system may only produce an EAFS of 25. The difference between these two speed values is not overly important as long as a particular system is capable of reproducing a particular speed at will.

The method for producing either is identical and is defined as 3/2H, where H is the exposure (in meter-candle-seconds) at the point on the characteristic curve where the density is 0.3 above base-plus-fog density. An example of this determination for color reversal materials can be found in figure 2-3. The sequence for determining this value is as follows:

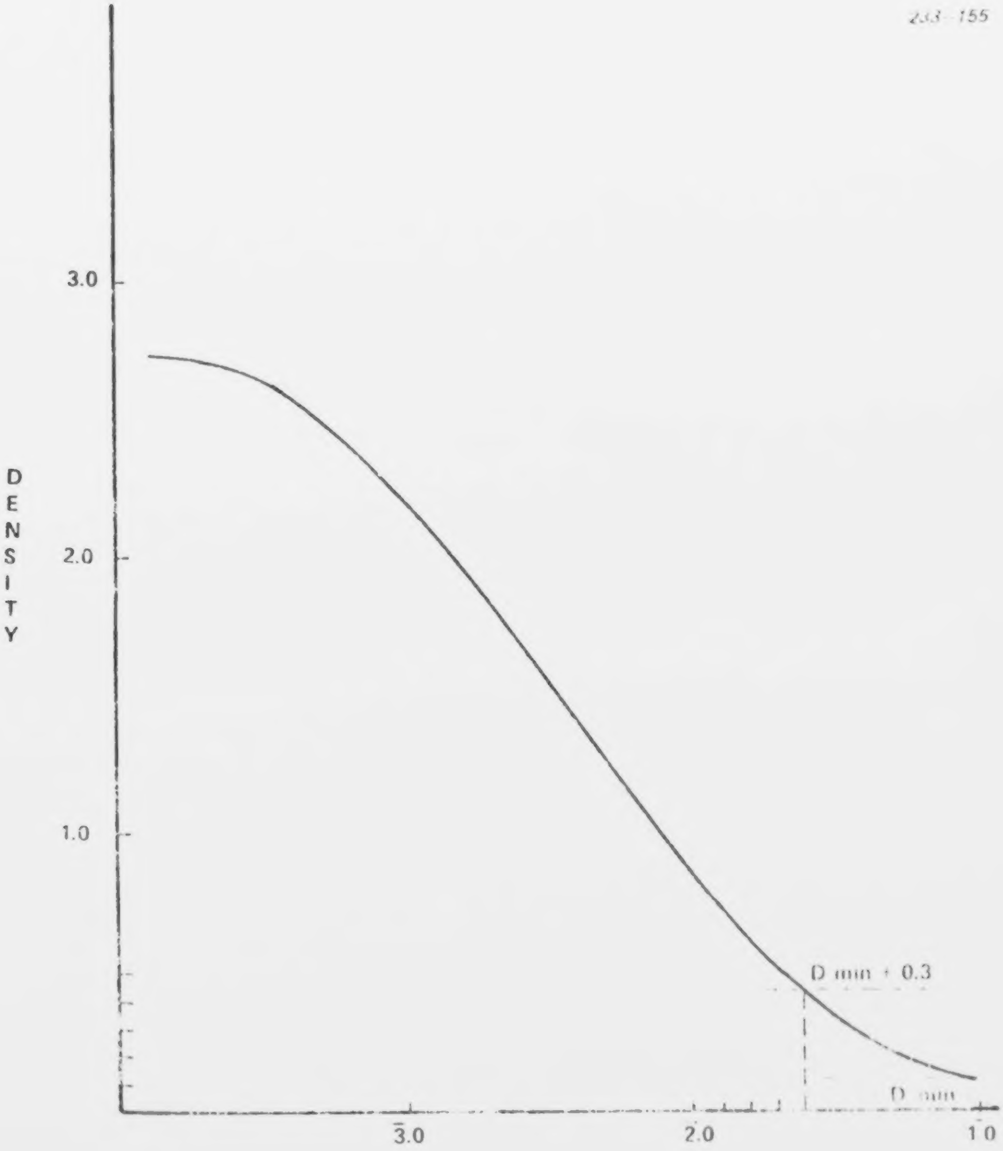


Figure 2-3. EAFS speed determination for color reversal film.

(1) After the test material has been properly exposed and processed to conform to production practices, determine the visual densities and construct the reversal D log H characteristic curve. Remember that the test material must have correct color balance before the speed values are determined.

(2) Locate the point on the toe portion of the characteristic curve that is 0.3 density units above minimum density (stain density).

(3) Determine the log H value which corresponds to that point (stain density + 0.3).

(4) Find the antilog of that value, which will be the exposure in MCS, multiply by 2, and then divide this product into 3.

As further illustration, follow the procedures listed below while viewing figure 2-3.

(1) The base-stain density for the illustrated curve in figure 2-3 is 0.12. Add 0.30 to this value and locate that point on the characteristic curve.

(2) The log H value produced at that density point is found to be 2.39. The antilog of this value is 0.0245; 0.0245 multiplied by 2 = 0.049.

(3) Next, divide 3 by 0.049 to yield 61. Therefore 61 is the EAFS for that film.

There is no ANSI standard method for determining the speeds of color films for aerial photography. Therefore, effective aerial film speeds are determined by experience or observation. Numerous aerial tests are made under various atmospheric conditions at different solor altitudes and different seasons of the year. Table 2-1 lists the effective aerial film speed numbers for current color aerial films.

Exercises (812):

1. List the methods for determining film speeds.

2. What does the speed of a photographic emulsion indicate?

3. Explain why Method B is variously known as USAF Maximum Shadow Detail or half-gamma speed.

4. How are effective aerial film speeds determined for color films?

813. State the characteristics of masked color negative material, and state the requirements for computing its film speed.

Masked Negative Color Film Speed Calculations. While reversal and unmasked negative materials speed values are based on visual densities, the masked color negative speed values must be determined by an entirely different method because of the masking.

The masking material within the emulsion layer (when the material has been exposed to light of the proper spectral quality, and processed to conditions that yield correct color balance) results in the three individual color layers being displaced vertically from each other. Because of this displacement, the AFS method of speed determination cannot be used for masked materials. Instead, the *Method For Determining the Speed For Color Negative Films For Still Photography*, as discussed in ANSI Standard PH 2.27–1965, and which describes the procedures for tricolor density analysis, is used.

The sensitometric techniques used for negative color film speed determinations do not differ greatly from those employed for reversal materials. The most important consideration, as with reversal materials, is that the processing of the test materials conform to production practices.

After the test material has been exposed and processed, the tricolor characteristic curves should be plotted for the Blue, Green, and Red sensitive layers. These curves must

TABLE 2–1

EFFECTIVE AERIAL FILM SPEEDS OF COLOR AERIAL FILMS

233-36

Effective Aerial Film Speeds of Color Aerial Films

KODAK AERIAL COLOR FILM (ESTAR THIN BASE) SO-242	6
KODAK EKTACHROME MS AEROGRAPHIC FILM 2448*	32
KODAK EKTACHROME EF AEROGRAPHIC FILM SO397*	64
KODAK AEROCHROME INFRARED FILM 2443*	40
KODAK AEROCOLOR NEGATIVE FILM 2445*	100

* (ESTAR BASE)

be parallel or color balance between the individual layers has not been obtained. This condition necessitates corrections be made in either the exposing or processing steps in order to obtain parallel tricolor curves.

The Green sensitive layer (middle layer) is used in masked negative color films to establish the speed point location for all three emulsion layers. This speed point is described as the reciprocal of the point on the log H axis that corresponds to 0.2 delta density between the density point 0.10 above minimum density and the density 1.30 log H units to the right of minimum plus 0.10 density. This is illustrated in figure 2-4. Therefore, the following sequence must be followed to determine the actual speed point.

(1) Determine the point on the toe of the Green sensitive curve that is equal to 0.10 above minimum density (point A).

(2) From that point, move right on the curve 1.30 log H units and determine the density at that point (point B).

(3) Determine 0.2 of the density difference and add this value to the minimum densities of all three curves (points C).

(4) Determine the log H values (for all three curves) which correspond to their individual speed points.

(5) Average these values to determine a single speed point.

(6) The film speed value is then found by determining the reciprocal of the exposures in MCS ($S = \frac{1}{H}$).

Referring again to figure 2-4, the Green speed point is found to be 2.02, the Red speed point is 2.21, and the Blue speed point is 2.18. This data must be coded by subtracting 2.00 from each log H value. These differences are then added, the sum divided by 3, and the quotient added to 2.00 (the value by which the individual exposures were coded).

$$\text{Log } H_m = \frac{(2.02 - 2.00) + (2.21 - 2.00) + (2.18 - 2.00)}{3} =$$

$$\frac{0.02 + 0.21 + 0.18}{3} = \frac{.41}{3} = 0.14 + 2.00 = 2.14$$

The antilog of 2.14 = 0.0138, which is the exposure in MCS. Therefore, the speed value for this color negative material would be

$$\frac{1}{0.0138} = 72.$$

Exercises (813):

1. Why can't masked color negative speed values be determined by visual densities?

2. How are the three individual color layers of the masked color negative placed in relation to each other?

3. What should you consider when you determine the sensitometric techniques for negative color film speed?

4. To obtain proper color balance, how should the curves appear between the individual layers?

5. What sensitive layer do you use to establish the speed point for all three emulsion layers?

6. In the formula $S = \frac{1}{H}$, the number 1 is the __________ of exposure in MCS.

814. State the factors that determine film speed for unmasked aerial color negative materials.

Film Speed Determination for Unmasked Aerial Color Negative Materials. As with other aerial color materials, no method for determining film speed values for unmasked aerial color negative materials has been devised. The method which has been suggested for use with masked negative materials cannot be applied for unmasked negative materials because of the different type density determinations used. While the masked negative color densities are plotted for each color layer, as necessitated by the masking material, the densities used for the unmasked test material should be of the visual density type.

Since film speed values are relative numbers based on the minimum exposure necessary to produce useful minimum density, any film speed method which utilizes visual densities can be used for unmasked negative materials. The exact method, however, must be determined by the using organization, and must be one that is best suited to that organization's production system.

One method that might be suggested at this time is the method described in ANSI Standard PH 2.34–1969. The procedures described in this Standard are those previously suggested for use for film speed determinations for aerial color reversal materials.

Again, as with the reversal color materials, color balance must be achieved, and processing standards must conform to production practices. Furthermore, in the case of unmasked negative materials, a negative D log H curve is constructed instead of the reversal curve. All other factors remain the same.

One advantage to this method is that the computed film speed value is the EAFS value and can be used in conjunction with the Aerial Exposure Computer, while those values for masked color materials cannot. This greatly simplifies the compensation necessary for atmospheric haze.

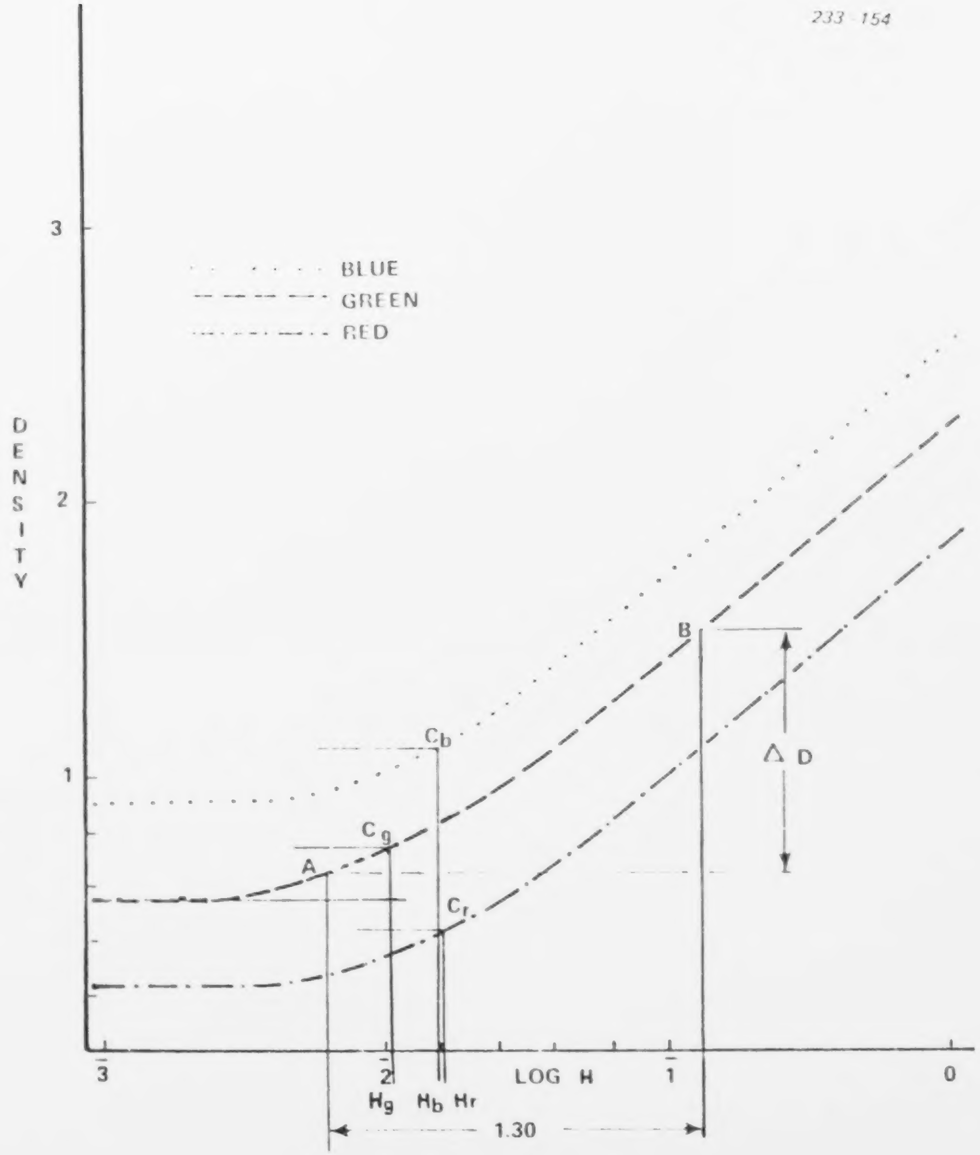


Figure 2–4. USASI speed determination for masked color negative film.

Exercises (814):

1. What type of densities do you use for determining film speed for unmasked aerial color negative material?

2. What are film speed values based on?

3. Who determines the exact method for finding film speed values?

815. List the factors that affect the capability of a photographic reconnaissance system, state the data that affords a correlation of these factors, and cite the system designed for the purpose of correlating these factors.

USAF Exposure Monitoring Control System (EMCS). Exposure is one of the more significant factors that affects the capability of any photographic reconnaissance system. Slight deviations from optimum exposure can cause serious degradation in resolution, and especially so in high imaging systems. The density values of the original negative must be controlled to prevent loss of intelligence. Since density is the product of both exposure and processing, it is essential that these two factors be closely monitored and correlated. Too frequently, an error in processing is attributed to exposure and vice versa; processing is often blamed for poor exposure.

The measured densities of the original negative (minimum-maximum) reflect the combined effects of exposure and processing. This data will afford the most accurate correlation of aircraft exposure and processing. The use of average minimum and aircraft exposure and processing. The use of average minimum and maximum densities incorporates statistical quality control techniques, eliminates subjective evaluation, and provides for more consistency in the original negative.

This system is designed for the sole purpose of correlating exposure and processing. The resulting data will be used to balance the exposure and processing to achieve maximum resolution. Formerly the effective film speed, Aerial Exposure Index (AEI) computed sensitometrically, was the only input from the imagery production unit to personnel tasked with the setting sensor exposure. This method does not faithfully reflect the photographic effect when films are processed to different gammas, as shown in figure 2-5. These curves are the same emulsion with identical sensitometric exposures, but processed to different gammas. It is quite obvious that curve B will render a darker negative than curve A, especially in the shoulder portion of the curve. For example, if a target was located at point C on the log H axis, the resultant densities would be 1.63 on curve A, and 2.05 on curve B. The highest density on curve B is a direct result of processing ONLY; however, it could easily be diagnosed as an exposure problem.

Further examination of the curves in figure 2-5 reflects that curve A has an AEI of 10.0 while the AEI of curve B is 5.5. If this data was used by sensor technicians for setting exposures, the film processed to curve A specifications would receive one-half the exposure as that to be processed to curve B specifications. Referencing the example (point C) in the above paragraph, it is quite evident there will be a serious exposure problem. The method for determining AEI has worked effectively and will continue to do so, provided it is used with a relatively high gamma process. Since the AEI computation is based on 0.6 gamma, an error results in the low gamma process; this allows the speed point to shift under the threshold of the sensitometric curve, resulting in an increased AEI, which is misleading with respect to the total photographic effect.

Exercises (815):

1. List the two factors that affect the capability of a photographic reconnaissance system.

2. What data reflects the combined effects of exposure and processing?

3. What was the sole purpose for designing USAF Exposure Monitoring Control System?

816. Identify and explain factors of the exposure control formula and identify the product of the low gamma formula.

Exposure Monitoring Control System Formula. The exposure control formula, figure 2-6, considers the total densities of the original negative. It is based on the same techniques discussed in the *trigradient system* with only a slight modification to that formula. Average density readings are used to minimize error. The data in the formula reflects a desired minimum density of 0.40 and a desired maximum density of 1.80 for a high gamma process. Only the desired maximum density (1.40) is changed in the low gamma formula because the toe of the process remains relatively constant while the gradient of the shoulder decreases. These figures can be changed to meet individual needs; however, the latitude of the film will be a limiting factor.

Procedures: Establish the desired total densities for the original negative based on the latitude of the film. Use the data in the formula in figure 2-6 unless special effects are desired.

- Take adequate density readings, usually a minimum of seven per roll, to establish an average for the minimum and maximum densities.

NOTE: If the original imagery has been read out for duplication, the average minimum and maximum densities

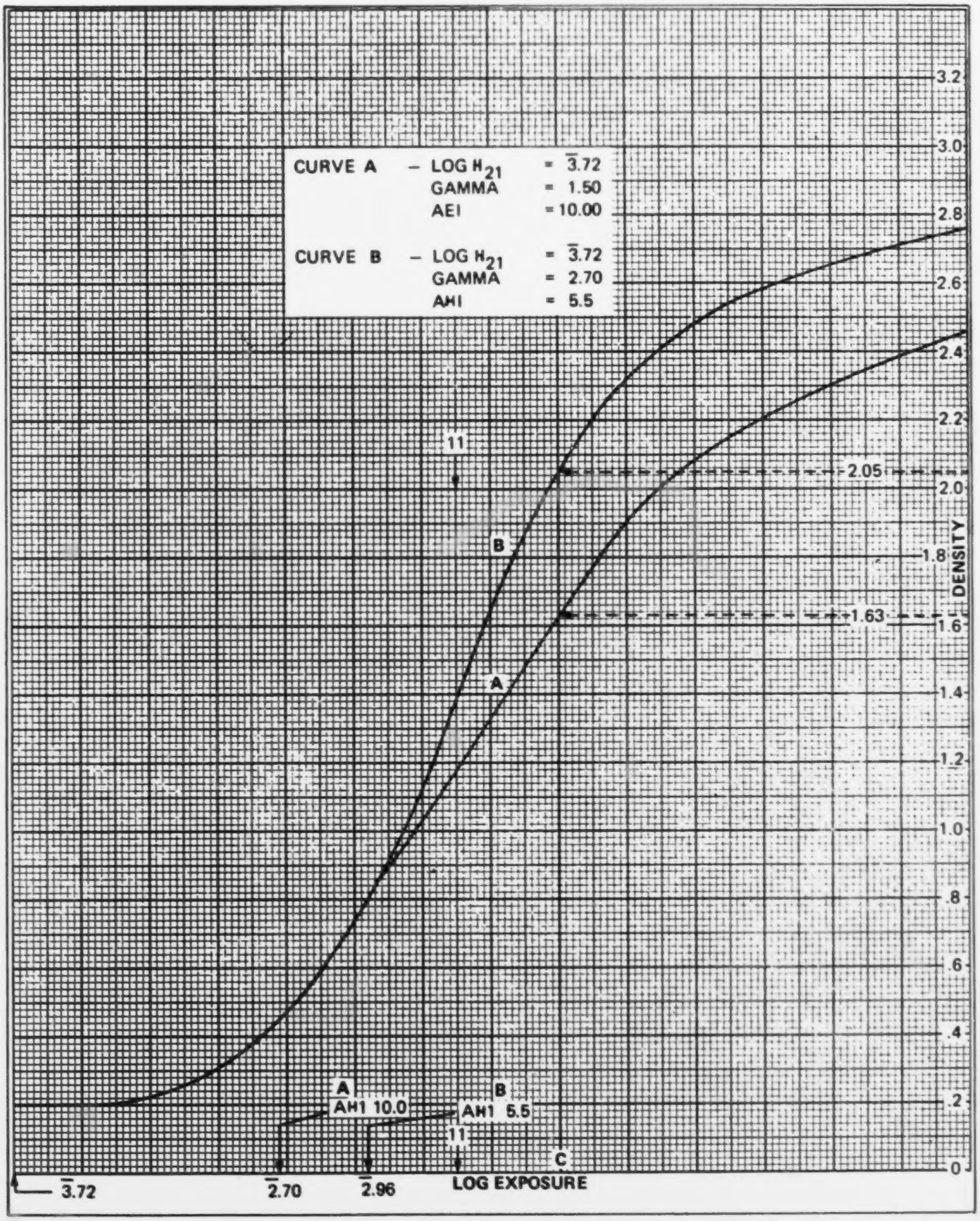


Figure 2–5. Aerial exposure index for high and low gamma process.

HIGH GAMMA PROCESS:

$$\frac{\left(\dfrac{\overset{\text{Actual}}{\text{D-Max + D-Min}}}{3}\right) - \left(\dfrac{\overset{\text{Desired}}{\text{D-Max + D-Min}}}{3}\right)}{0.30 \text{ (One full f/stop)}} = X$$

HIGH GAMMA PROCESS:

Where: Actual D-Max = Reading from original negative.
Actual D-Min = Reading from original negative.
Desired D-Max = 1.80
Desired D-Min = 0.40
X = Variance from Optimum Exposure.

LOW GAMMA PROCESS:

Where: Actual D-Max = Reading from original negative.
Actual D-Min = Reading from original negative.
Desired D-Max = 1.40
Desired D-Min = 0.40
X = Variance from Optimum Exposure.

NOTE

If X is positive, the amount of OVER EXPOSURE is reflected in f/stops.

If X is negative, the amount of UNDER EXPOSURE is reflected in f/stops.

Figure 2-6. Exposure monitoring control system formula.

that were utilized for printing instructions, base + fog (also referred to as gross fog) can be used in this formula. (Base + fog is the combined densities of the film base and the density of the processed, unexposed portion of the photographic emulsion.)

- Substitute actual values in the formula to determine the amount of overexposure or underexposure.
- Do not, *repeat, do not* over react to minute variations from the desired.
- The data obtained should be plotted on a control chart to permit continuous monitoring for trends, etc.

Example: For specific instructions for the formula, refer to figures 2-7 and 2-8. In figure 2-7 the actual densities have been plotted on the original negative process curve, reference points H–1. The data from the formula indicates the photography is overexposed by 1/2 f/stop. If the exposure is decreased by that amount, both minimum and maximum densities will be affected. The resultant densities have been plotted, reference points H–2, by shifting the Log H units by 0.15. Figure 2-8 indicates an underexposed problem, and the calculations and adjustments are made in the same manner.

Exercises (816):

1. What factors are considered when using the exposure control formula?

2. The data presented in the formula reflects what density readings for a high-gamma process?

3. Why is only the desired maximum (1.40) changed in the low-gamma formula?

2-3. Development Control

We have seen that changes in development can also change the character of the H and D curve; therefore, it is logical that the curve should be used to monitor and control development. You found that development can be extended until gamma infinity is obtained (fig. 1-14). When this happens, the effect of further development is seen mainly in the fog level. The point at which gamma infinity occurs varies mainly with the emulsion, and this provides valuable information concerning films. However, since this point is also affected to some degree by the developer used, it is usually considered in terms of film-developer combinations. But more important than the fact that an emulsion reaches gamma infinity is the fact that intermediate positions of its slope correlate to the development given. By plotting the changes which occur against the factors causing them, we can establish some very useful processing controls.

817. Tell how you select a processing time to obtain a desired gamma and state the rationale for the procedure.

Time-Gamma and Time-Fog Curves. Because processing results are quite consistent for a given film-development combination, you can construct a chart that allows you to select a particular processing time to obtain a desired gamma. To construct such a chart, you would first plot a family of curves developed at varying time, with constant agitation and temperature.

Figure 2-9 illustrates a family of five curves developed in a given developer for 3, 6, 9, 12, and 20 minutes. (More curves would provide additional points and would increase the validity of the process; but five points will give reliable results, and three is the minimum requirement.) In this example, the test strip which received the 3-minute development reached a gamma of 0.50; the strip developed for 6 minutes reached a gamma of 0.75; a gamma of 0.90 resulted from the 9-minute development; the 12-minute strip attained a gamma of 0.98; and the 20-minute strip reached 1.0. These gamma values are plotted against their development times on a graph conveniently located in one corner of the larger graph. The points are then connected with a smooth curve that extends just beyond each of the outermost points. The family of curves which you plot for your time-gamma chart will generally show slight differences in base-fog levels at the various developing times, and these differences can be plotted on the time-gamma chart, as shown in figure 2-9.

Exercises (817):

1. Why should you provide a family of curves for a given film developer combination?

2. How many curves are required to provide validity and reliability to the process?

818. Explain why a time-temperature chart is useful and what it reveals.

Time-Temperature Charts. Another chart that is extremely useful in process control is the time-temperature chart. This is actually a time-temperature-gamma chart, since its purpose is to indicate time-temperature combinations to produce a given gamma. The charts, published by film manufacturers, indicate recommended gammas for ordinary photographic applications. However, the requirements of imagery production laboratories sometimes call for radical departures from the ordinary, and you would need to plot time-temperature charts for a particular project.

To construct a time-temperature chart, start with two time-gamma curves plotted from families of curves processed at different temperatures. While any reasonable

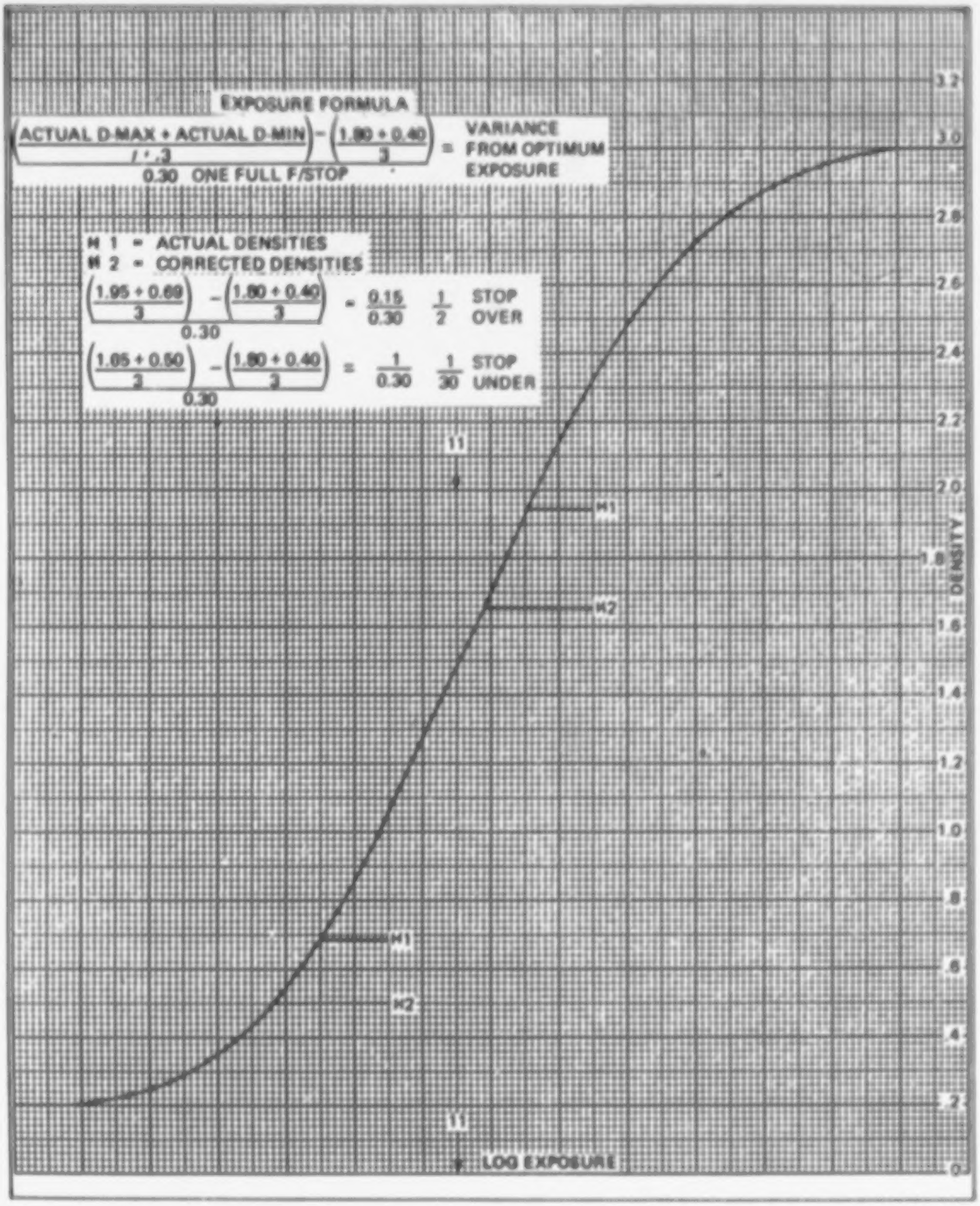


Figure 2-7. Graph of an overexposure condition.

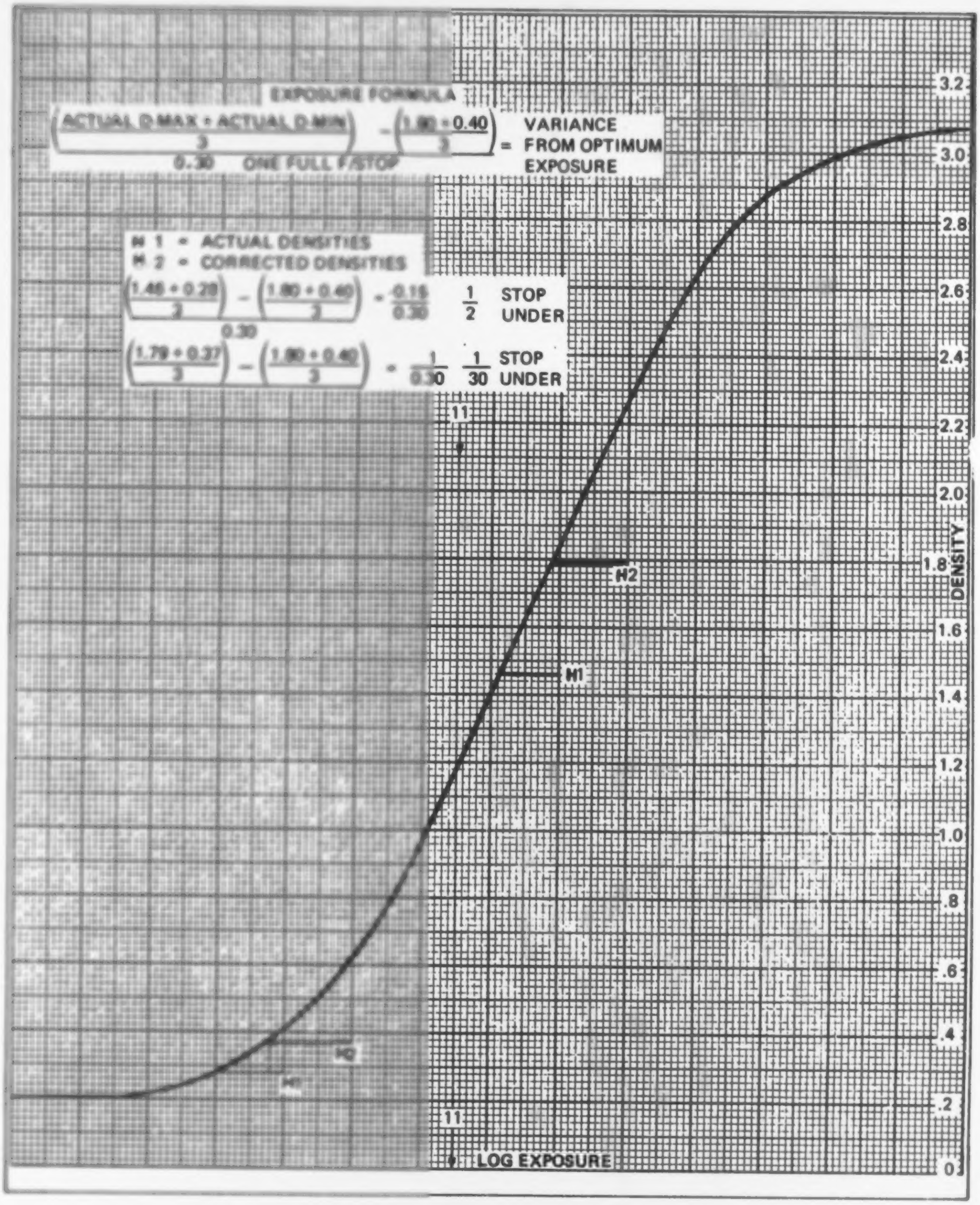


Figure 2-8. Graph of an underexposure condition.

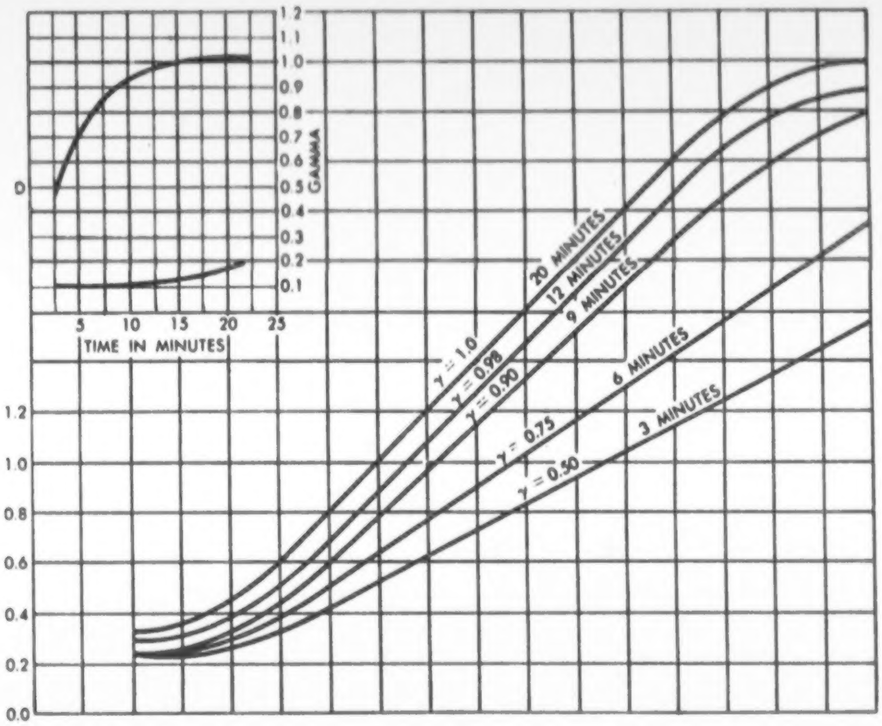


Figure 2–9. Family of curves.

temperature interval may be used, it should not be less than 10° F. The selected gamma is read on both time-gamma curves, with the time being plotted against the temperature. A straight line is then drawn through the two plots, as shown in figure 2-10. This step is repeated for each gamma value you want to plot. Note that the temperature is plotted in regular increments, while the time is plotted logarithmically. Semilog graph paper can be obtained for this purpose.

Exercises (818):

1. Why is a time-temperature chart useful, and what does it reveal?

2-4. Tone Reproduction

The image in a photograph can be seen because of the different tones that are present within the various areas. If your eye can recognize the photographic image as a copy of the original subject, it is due to the close relationship between the tones of the image and the luminance of the original, even though both the tones and the luminance are variables. When "tones" describe the close relationship between the original subject and its photographic image, it is referred to as *tone reproduction*.

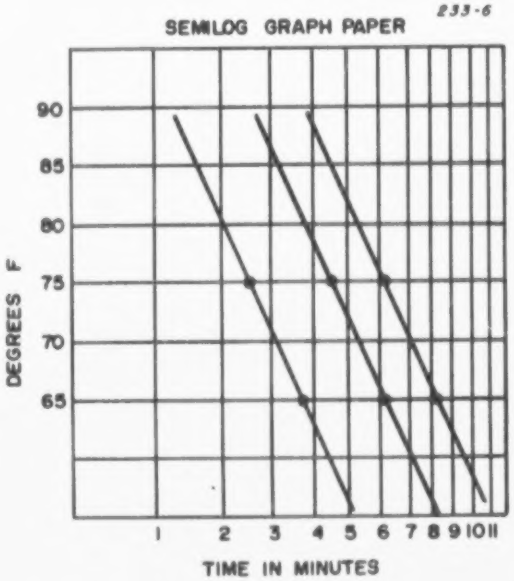


Figure 2–10. Time-temperature chart.

As an imagery production technician, you know that a number of steps are needed before a photographic reproduction is finished. Someone else exposes the negative of the original scene, but you undoubtedly will be called upon to process the film. Once the film is processed, either contact or projection prints must be made from the negative. In each of these steps, the result will have some bearing or effect (contrast, grain, color sensitivity, etc.) on the appearance of the final positive image. To study tone reproduction or to effect tone reproduction control, you must take into account each of the steps involved. Let us begin our discussion by delving into tone reproduction control, which considers factors that affect the quality.

819. Explain the factors controlling tone reproduction.

Tone Reproduction Control. In any photographic reproduction cycle, some kind of tone reproduction control is exercised. Usually, in noncritical photography, this consists of a purely visual evaluation. But as the requirement becomes more and more exacting, greater but less subjective controls must be used. In any precision facility, all factors which could lower the quality of the final product must be understood; and this requires considerable investigation of tone reproduction parameters.

Tone reproduction studies are primarily concerned with the tonal relationship between the subject and reproduction. They also tell us how these relationships are derived and how they may be used in the analysis of problems of quality control. Considered objectively, tone reproduction studies deal with quantitative relationships, especially those which are derived photometrically.

The early tone reproduction studies were concerned with reproducing the average scene in such a way that the range of luminance in the scene was represented by a believable range of densities in the print. Trial-and-error methods failed to satisfy the critical worker, who felt that some objective method of tone control was needed. It was felt that the sensitometry of negative and positive could be used in some way to predict a photographic result. Figure 2-11 illustrates the way this was done.

In quadrant I, the densities of the negative D are plotted against the log luminances of the corresponding areas of the scene, log B_o. The minimum luminance is represented as

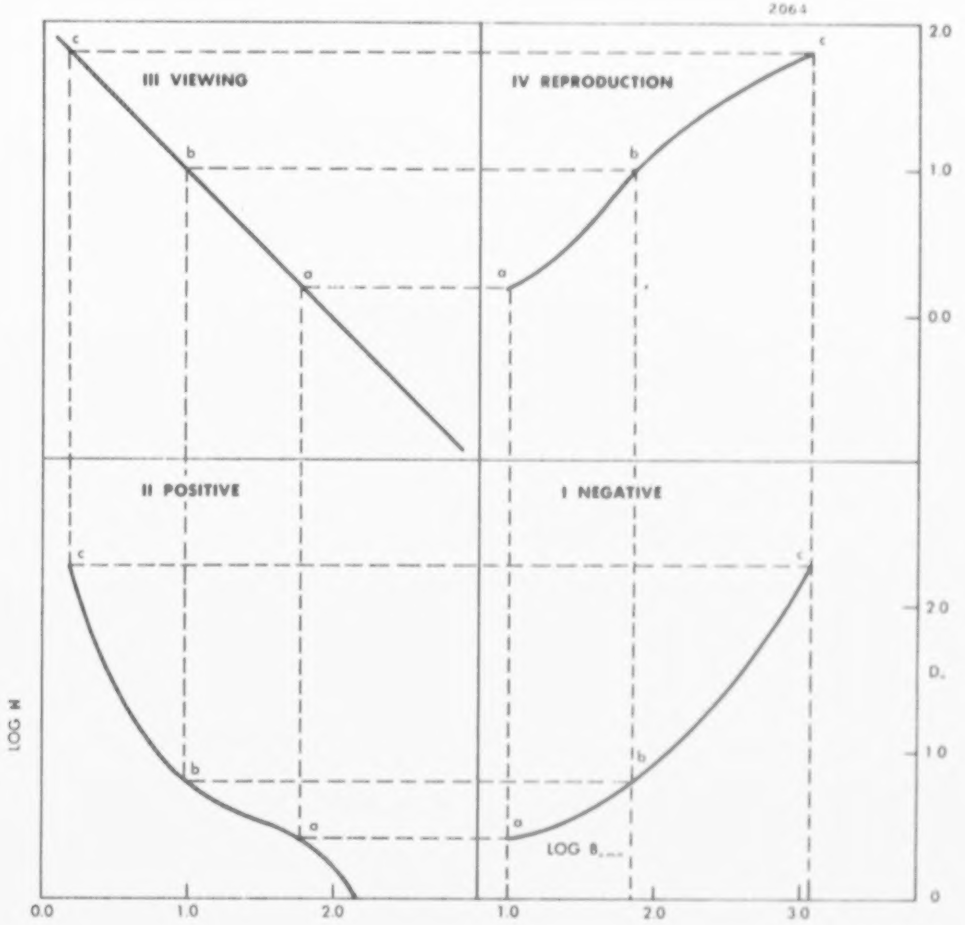


Figure 2-11. Basic tone reproduction control diagram.

point a, and the maximum luminance is represented as point c in the curve. The resultant curve corresponds to the D log H curve of the negative material.

The characteristic curve of the positive material is plotted in quadrant II. (Turn the page 90° counterclockwise to see how the curve is oriented in the diagram.) In this illustration, the minimum negative density, point a on the negative curve, is aligned with point a on the shoulder of the positive curve, and so forth.

The function of the 45° line in quadrant III is to transfer the plots of the negative and positive curves to quadrant IV. It represents viewing conditions which are free of glare; thus, it does not alter the luminances of the print. The dashed lines are construction lines by which any point on any curve can be related to corresponding points on all of the other curves. Where these lines intersect in quadrant IV are the plots which comprise the tone reproduction curve. This diagram does not take into consideration any of the other factors—such as camera flare, haze, and printing systems—which affect tone reproduction; therefore, to tell the whole story, the diagram needs to be extended.

Perhaps the best place to begin extending our study of tone reproduction diagramming is with conventional cameras and average scenes. Also, we should define some of the terms used in this study. The familiar term "brightness," when applied to the objects in scene, is used to describe the psychological properties (visual impression) of the scene. To differentiate between psychological and psychophysical considerations of the same condition, the term "luminance" is used to describe the measure of photographic brightness. The physical aspect of brightness, or luminance, is called *radiance*. Similarly, the physical property of reflectance has the psychophysical property, *luminous reflectance*. These terms describe the objects in the scene when light falls upon them. The light, called *illumination*, is referred to as illuminance in this context.

Scene luminance scale. The scene luminance scale is the ratio of maximum to minimum luminance values of the scene. Under uniform illuminances, the scale would be of the order of 90 to 95 percent, since the best reflectors reflect only about 98 percent, and the best absorbers will reflect as much as 1 or 2 percent. However, few scenes are uniformly illuminated. Objects in shadow areas receive very little light to reflect, hence are darker. Thus, the scene luminance scale can be greater for nonuniformly illuminated scenes than it can be for evenly illuminated scenes.

Until about 1940, it was generally believed that the average scene luminance scale was approximately 30:1, or a log luminance scale of 1.5. But experiments indicated that of 126 exterior scenes measured, luminance scales ranged from 27:1 to 760:1, with an average scale of 160:1. Later, investigators measured scenes having luminance scales greater than 1000:1. To reproduce all of the tones of such a scene, a printing material would have to have a density scale of at least 3.0. While this is possible with transparency material, it is not with paper. If paper prints are to be made, it is necessary to decide which tones are to be retained and which are to be sacrificed. By applying tone control diagramming techniques, it is possible to make an intelligent decision. Of course, the final result will have to be viewed and evaluated.

The luminance scale of most scenes can be measured using a telescopic luminance photometer with a small-look angle and directing its receptor at the various luminances in the scene. The readings are in foot-lamberts, and the luminance scale is the ratio of the maximum to the minimum. Luminances, as measured in a typical scene for light-to-dark areas, may be as follows:

Area	*Foot-Lamberts*
a	4830
b	1600
c	780
d	500
e	130
f	10.5

The luminance ratio of this scene is 4830/10.5 or 460:1. That is a log luminance range of 2.66.

Camera image. An ideal situation would be for the luminance of the objects in the scene (shown symbolically as B_o) to be directly proportional to the luminance of the image in the camera (shown as I_o), but in practice, such is not the case. The relationship of the object may be stated as:

$$I_o = B_o/f^2K$$

where

I_o = image illuminance
B_o = object illuminance
f = lens aperture ratio
K = constant

This is the equation for the straight line at 45° to the axes of the coordinate system. If the value of K is known, the luminance measurements made on the object can be converted directly to illuminance values of the image. In the majority of cases, only relative values of illuminances are necessary for tone reproduction studies, so any arbitrary value for the constant K may be established. Thus, we are able to describe the camera image in terms of the object producing it.

The object on the image plane (focal plane of a camera) is affected not only by the image-forming light originating at the subject but by the non-image-forming (flare) light within the camera as well. This flare light is the result of reflections from lens mount, diaphragm, shutter blades, barrel, and from interreflections between the glass-air surfaces of the lens. It produces a somewhat evenly distributed veil of light of low intensity over the entire image plane. It has the effect of lowering contrast, especially in the shadow areas.

The effect of flare is greatest in the thin areas of negative and least in the areas of maximum density. Although flare light is an integral part of the light producing the image in the negative material, we can assume that there is a camera image separate and apart from the flare image. Let us think of the camera image as coming directly from the object and of the flare image as being merely a veil of light over the entire image plane.

Flare image. The flare image increases the illuminance evenly over every portion of the camera image and, by so doing, reduces its contrast. The presence of flare light has the effect of compressing the illuminance scale of the image. This effect is explained by the following example:

$$I_i = I_{io} + I_{if}$$

where I_i = the total image illuminance, I_{io} the illuminance due to image forming light, and I_{if} = the image illuminance due to flare light only.

The illuminance scale of the camera image is found by

$$IS_{io} = I_{iomax}/I_{iomin}$$

assuming I_{iomin} to be 0.01 foot-candle, I_{iomax} to be 1.00 foot-candle, and I_{if} to be 0.02 foot-candle, then

$$IS_{io} = 1.0/0.01 = 100$$

and adding the flare light

$$IS_i = \frac{1.00 + 0.02}{0.01 + 0.02} = 34$$

the total illuminance scale. Thus, the illuminance scale is compressed from 100 to 34 by the presence of flare light.

The effect of flare light can be demonstrated graphically, as shown in figure 2-12. Curve 1 is characteristic curve of a typical negative material and is plotted from sensitometrically determined measurements. This curve shows relation between density and the logarithm of the exposure incident upon the material. In the camera, this would be determined by I_i, the total image illuminance. If the exposure times were constant and there were no flare light in the camera, the relation between negative density D_n and object luminance B_o would be identical to that seen in the D log H curve. Curve 1 is a D log H curve of the negative material. Curve 2 between points D′ and A′ is the D log B_o curve of a particular negative.

The log B_o values shown at the top of the graph are arbitrarily set log 3.0 greater than the corresponding log H values seen at the bottom of the graph. Let us assume that the scene photographed had the maximum and minimum luminance indicated on the chart. These values represent the limits of the log luminance scale B_{so}. With no flare light in the camera, the minimum density of the negative will be seen at point D on curve 1, and the maximum negative density will be seen at point A of curve 1.

Now, let us see how the characteristic of the negative is altered by the addition of flare light. Consider the presence of flare light as a constant increment of exposure added to the exposure which forms the camera image. In the figure, the amount of exposure due to flare light alone is shown at point H_f on the log H axis. The density resulting from this exposure would correspond to the point on curve 1 intersected by the horizontal line labeled "Flare." This would be the minimum density produced in the negative if the minimum luminance of the scene was zero. Because this situation is most unlikely, the flare light exposure H_f must be added to the minimum camera image exposure H_{omin} to produce the exposure H'_{min}. The density (point B on curve 1) produced by the exposure H'_{min} becomes the minimum density of the negative. Plotting this density as a function of minimum image luminance produces point D′ on the chart. The maximum negative density C is produced by the combined flare light exposure H'_{max} and the minimum camera image illuminance H_{omax}. Plotting this density as a function of maximum subject illuminance gives us point A′.

You can obtain sufficient points to plot curve 2 by selecting other values of image illuminance, adding flare light and computing exposure, and plotting corresponding densities from curve 1 as a function of subject luminance. The curve in figure 2-13 is derived from the basic equation:

$$I_i = I_{io} + I_{if}$$

Selected from different points in the scene the log B_o is plotted against the log I_i of the corresponding points in the camera image.

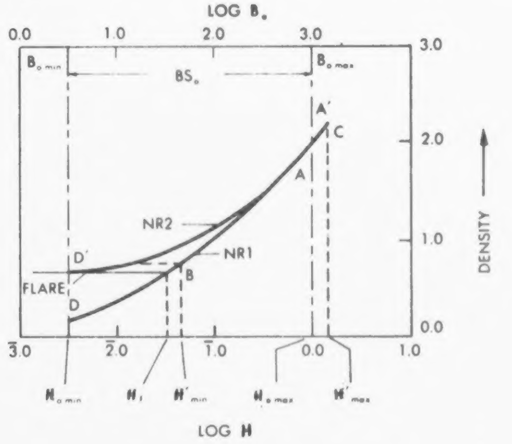


Figure 2–12. Effect of flare.

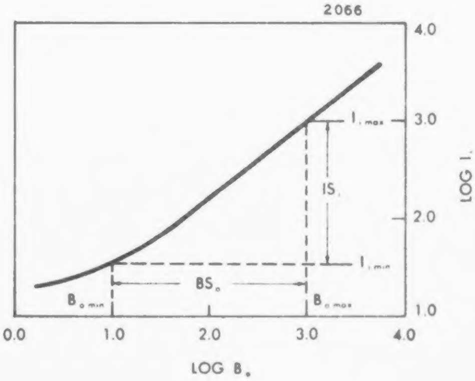


Figure 2–13. Typical flare curve.

If there were no flare light in the camera, the image illuminance and a straight line having a slope of unity would result. In that event, the relationship would be

$$I_i = I_{io}$$

But the presence of flare light added to illuminance due to camera image brings about a curve similar to that shown in figure 2-13. The shape of the curve depends upon the amount of I_{io} and I_{if}; thus, if the flare light is small, the flare curve becomes nearly straight.

Flare curve. Since flare light is present in any camera and has the effect on the image just stated, it is desirable to include a flare curve in our tone reproduction diagram. And, since it is the first consideration, it seems logical that the flare curve should occupy the first block of our diagram, as shown in figure 2-14.

Perhaps the most valid method of deriving the flare curve would be to use instruments that measure light values of the camera image and the total amount of light in the image plane, but such instruments are not practical for field work. However, by using the following method, satisfactory measurements can be obtained.

(1) Measure, photometrically, the values of maximum object luminance (B_{omax}) and minimum object luminance (B_{omin}). That is, take photometer readings of the highlight and the shadow areas of the scene.

(2) Determine the densities in the negative which correspond to the values of B_{omax} and B_{omin}.

(3) Determine the image illuminance scale. Plot a characteristic (D log H) curve of the negative material and ascertain the exposure values which correspond to the maximum and minimum negative densities. These exposure values are equal to the camera image illuminance scale IS_i, which is the ratio of the maximum image illuminance to the minimum image illuminance.

$$IS_i = I_i max/I_i min$$

(The characteristic curve should be derived from an intensity scale exposure so that the results conform to practice.)

(4) Determine the luminance scale of the subject, BS_o. If you consider BS_o as the ratio of the maximum object luminance (B_{omax}) to the minimum object luminance (B_{omin}), the scale can be computed directly from measurements of these quantities in the equation

$$I_o = B_o/f^2K$$

where

I_o = image illuminance
B_o = object illuminance
f = lens aperture ratio
K = constant

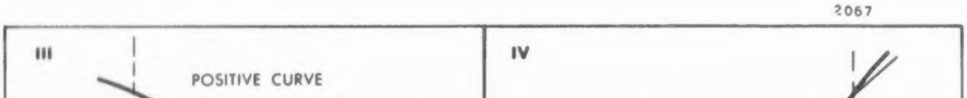


Figure 2–14. A typical IV quadrant tone control diagram.

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(5) Compute the amount of flare light. The effect of flare light upon the total image illuminance may be regarded as equivalent to the addition of a constant increment of luminance Δ B to all of the luminances in the scene. Thus,

$$I_i max = B_o max + \Delta B) \cdot K$$

and

$$I_i min = (B_o min + \Delta B) \cdot K$$

where K = the constant of proportionality. With these equations, we can obtain an expression for the evaluation of B in terms of B_{omax} BS_o, and IS_i. These quantities can be determined experimentally without much difficulty. This expression is

$$\Delta B = \frac{B_o max (1 - IS_i/BS_o)}{IS_i - 1}$$

By referring to the procedures shown in figure 2-13 and the following example, the flare curve can be plotted. For this example, assume that

B_{omax} = 1000 foot-lamberts
BS_o = 100
IS_i = 30
K = 1

Apply equation

$$I_i = (B_o min + \Delta B) \cdot K$$

and substitute values, we obtain

$$100 (1 - \frac{\frac{30}{100}}{30 - 1} = 24.1$$

The measured maximum and minimum subject luminance values are set down on the log B_o axis of figure 2-13.

Still working with relative values, the total image illuminance I_i (corresponding to any value of B_o) is computed and plotted in its proper relationship on the graph. Let us assume the value of I_i to be numerically equal to the sum of B_o + B (K = 1). Thus

$$B_o min = 10 + I_i min = 10 + 24.1 = 34.1$$

$$B_o max = 1000 + I_i min = 1000 + 24.1 = 1024.1$$

When this procedure is followed, use the intermediate value of B_o to obtain sufficient points for drawing a curve. This curve becomes the starting point from which a tone reproduction diagram is developed.

The ratio,

$$BS_o/IS_i$$

is known as the flare factor (FF). The flare curve relationship needs only to be based upon the maximum-to-minimum luminance ratio (sometimes called object contrast). This is the ratio we call the luminance scale of the object, BS_o.

The negative curve. In tone reproduction studies, the most important consideration of the negative D log H curve is the shape characteristics of the toe and straight-line portions. You need not be particularly concerned with shoulder characteristics because most present-day emulsions have such wide latitude that exposures in that area seldom occur. Thus, it is the length and gradient relationships of the toe region and the length and gradient of the straight-line portion that have the greatest bearing upon tone reproduction.

The degree to which the tone reproduction of the final positive is affected by the shape of the D log H curve depends upon the portion of the curve used in producing the camera image. This naturally is determined by the camera exposure given. You should be aware that the characteristics of a negative which make use of the toe portion of the curve are materially different from the characteristics of a negative using the straight-line portion only.

It cannot be emphasized too strongly that the D log H curve used in tone reproduction analysis be made, as nearly as possible, under conditions which conform to practice. The exposure of the sensitometric strip should be intensity modulated. The exposure time should approximate the camera exposure. The exposing illumination for both the strip and the negative should be similar in spectral quality. Finally, if it is at all possible, both the strip and the camera negative should be developed together.

The positive curve. In the process of producing a positive print from a photographic negative, it is usually necessary to suit the positive material to the negative rather than attempting to produce a negative for a particular positive material. Positive materials, particularly paper, generally have density scales that are much shorter than most negative materials. This is why many photographic printing papers are provided in a number of different grades. Also, the surface characteristics of printing papers are a major factor as to maximum densities produced. Therefore, quadrant III should be concerned with a particular positive material (of a certain surface and grade) which has been exposed and processed under certain conditions.

If you refer to figure 2-14, you will note that the positive log H axis is parallel to the negative density axis, with the values increasing in opposite directions; the reason is that the negative densities become the relative log H values for the positive, and the negative densities correspond to and may be used as the positive log H differences. As you might suspect, these values are reversed because large densities in the negative result in small exposures in the positive. Note, also, that the positive densities increase in a downward direction in the figure.

The positive curve need not be confined to photographic paper. Any material used for printing positives, including film and glass plates, may be analyzed in this way.

Exercises (819):

1. In those cases where accuracy of tone reproduction is not critical, what kind of control is permitted?

2. Tone reproduction studies are primarily concerned with what relationships?

3. What are the various quadrants of a tone-reproduction diagram?

4. Where is the best place to begin the study of tone-reproduction diagramming?

5. Define scene luminance scale.

6. How is the luminance scale of most scenes measured?

7. The object on the focal plane of a camera is affected by what two factors?

8. Where is the effect of flare the greatest?

9. What effect does this flare image have on the contrast of the negative?

10. Why is it desirable to include a flare curve in the tone-reproduction diagram?

11. In tone-reproduction studies, what is the most important consideration of the negative D log H curve?

12. In the process of producing a positive print from a negative, how do you select the material?

820. Given situations shown in tone reproduction curves, state the reason for them, and identify factors to consider prior to graphic analysis.

Analysis of Tone Reproduction Curves. As you may have observed, the shapes and positions of the curves in quadrants I, II, and III are determined by specific factors of each problem. The flare curve depends upon the amount of flare present in the particular camera used. The negative curve reflects the type of material used and the exposure and development it received. Similarly, the positive curve depends upon the nature and treatment of the positive material. It is the relation of these curves to each other which decides the character of the tone reproduction curve in quadrant IV. Note, also, that the slope of the reproduction curve at any given point is equal to the product of the slopes of corresponding points on all of the previous curves.

Graphic diagrams. Before starting a graphic analysis of tone reproduction, it is well to make a preliminary analysis of your problem. Consider the conditions of the scene being photographed, the negative material being used, the flare light present in the camera, the exposure given, and the kind and the amount of processing given the negative. Try to anticipate what effect the toe-shape characteristics of the negative material will have upon the tone reproduction when the negative is to be printed on the positive material in question. When you have done this, proceed with the construction of a tone reproduction diagram by observing the following:

(1) Locate two points, a_f and c_f on the B_o axis of quadrant I shown in figure 2-15. Point a corresponds to the minimum object luminance, and point c corresponds to the maximum object luminance. It has been experimentally determined that the maximum and minimum luminances for the average scene are 2300 and 14.5, respectively.

(2) Following the procedures outlined earlier in this text, plot the measured values of IS. The flare factor for the average camera is 4, the total image scale is 40, and the Δ B, as computed by equation

$$B = \frac{B_o max\,(1 - IS_i/BS_o)}{IS_i - 1}$$

is 44. The logarithms of the B_{omin}, B_{omax}, and intermediate B_o, values are plotted on the graph against the total image illuminance value I_i, computed according to equations

$$I_i max = (B_o max = \Delta B) \cdot K$$

and

$$I_i min = (B_o min + \Delta B) \cdot K$$

Join the plotted points with a smooth curve.

(3) Quadrant II is turned 90° counterclockwise from quadrant I. A D log H curve of the negative material is positioned so that the minimum camera exposure which will produce a good print corresponds to the Log B_{omin} (point a_f) of the flare curve. (This may be set at the speed point for USASI film speed.) This point, as in figure 2-15, is located by extending a horizontal line from point a in the flare curve. Points b_n and c_n are located in a similar manner. Curves 1 and 2 are drawn to illustrate the effect of materials having short- and long-toe characteristics, respectively.

(4) Place the characteristic curve of the positive material in quadrant III. If the positive material is paper, select a grade having a long exposure scale approximately equal to

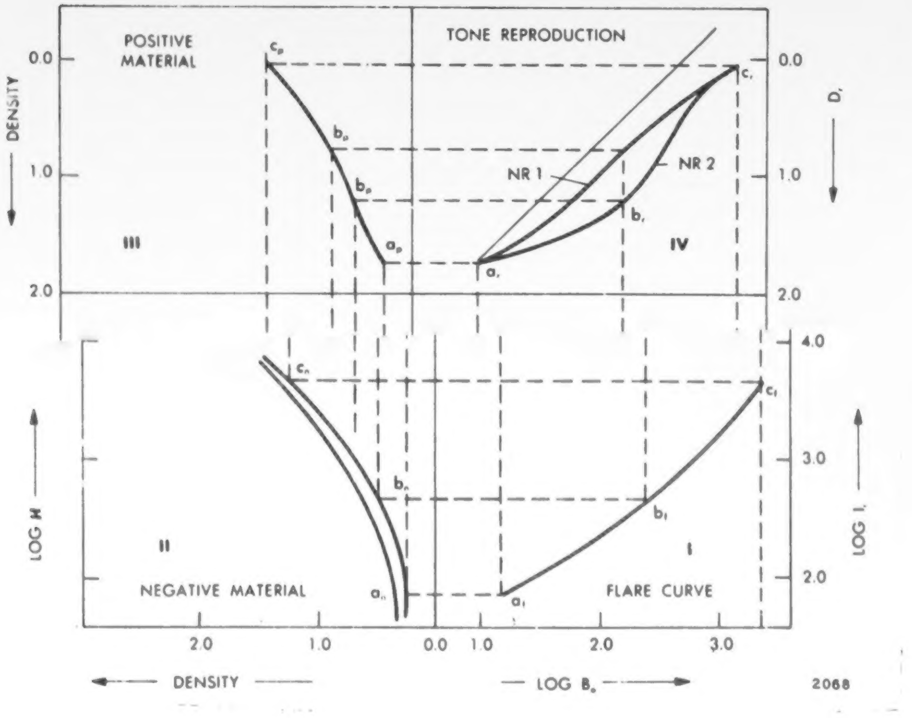

Figure 2–15. Tone reproduction curves produced by two different negative materials.

the density scale of the negative. Draw a line vertically from point a_n into quadrant III. Find a point on the curve where the gradient is equal to the average gradient (G) of the paper curve. Position the curve in quadrant III so that this point (called a_p) is intersected by the vertical line from point a_n. Note that the negative and the positive curves are parallel to each other but that the density values are reversed. This, of course, is because the least density in the negative produces the greatest density in the print. Points b_p and c_p are found by extending vertical lines from points b_n and c_n until they intersect the curve. Positives on film or on plates are handled in a similar manner, but the characteristic curves produced by such materials differ considerably from paper curves. They may resemble the negative curve more closely; however, the reversed and inverted relationship still exists.

(5) The tone reproduction curve in quadrant IV results from connecting the points (a_r, b_r, and c_r) where the horizontal lines extending from the positive curve intersect the vertical lines extending from the flare curve. If there were not flare light in the camera and if the negative and positive were exactly matched, the tone reproduction quadrant would contain a straight line of 45°; however, any changes occurring in the flare characteristics, the negative material, of the G of the positive material will cause characteristic changes in the tone reproduction curve. The two curves in figure 2-15 show the effect of a change in toe-shape characteristics in the negative material.

Diagram analysis. To analyze the curves of figure 2-15, note that both curves lie below at 45° line. This line is placed at the toe of the reproduction curve to evaluate the response in relation to the shadow densities. Quite often, the 45° line is placed so that it corresponds to the B_{omax}. When this is done, the ideal response is related to that portion of the scene least affected by flare.

Position of the reproduction curves in figure 2-15 indicates that the reproduction is dark because density increases in a downward direction in quadrant IV. Also, the average slope of the curves (being less than 45°) indicates that the reproduction is flat. The density of the reproduction can be corrected by shifting the position of the positive curve to decrease the exposure. Likewise, the means by which negative and print contrast are increased may be used to bring the reproduction curve closer to the 45° angle, if that is the desired result.

The changes in tone reproduction curves, brought about by changes in the various factors, are illustrated in figure 2-16. These cases are extreme but not unreasonable. In figure 2-16, A, curves 1 and 2 are those of figure 2-15. They show the effect of the changes in toe-shape characteristics of the negative material.

In figure 2-16, B, curves 3 and 4 show changes due to the luminance scale of the scene. Curves 5 and 6 in figure 2-16,C illustrate possible changes due to differences in flare light. This situation can occur when two different cameras are used to photograph the same scene. The camera that

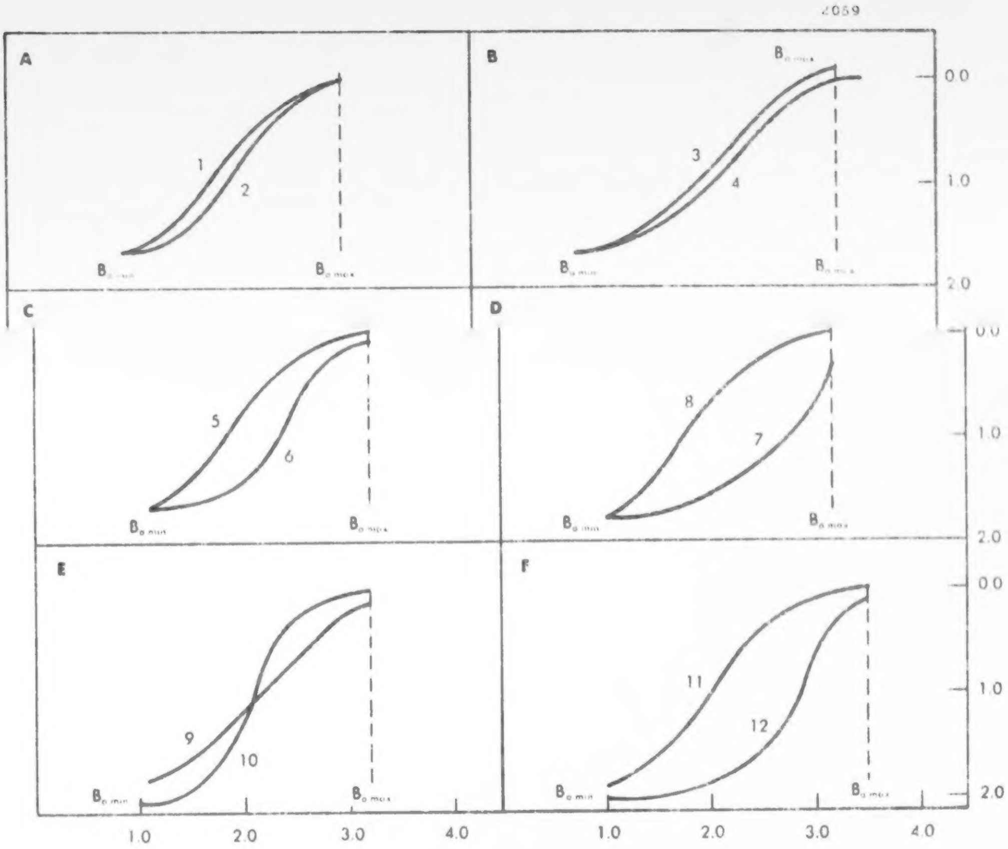

Figure 2–16. Analyses of tone reproduction curves.

produced curve 5 had a minimum of flare, whereas considerable flare was present in the camera which produced curve 6. By changing the level of exposure in the camera, you can produce the curves shown in figure 2-16,D. Curve 7 is the product of an exposure that is two stops less than required for an excellent print. Curve 8 is the result of an increase of two stops over that needed for an excellent print. If you have changed the grade of printing paper from grade 0 to grade 4, curves 9 and 10, shown in figure 2-16,E, are produced. Finally, altering the printing exposure level affects the changes illustrated in figure 2-16. Curve 11, in this case, resulted when printing solely for the shadow detail, whereas printing exclusively for the highlight detail produced curve 12.

By studying these effects, it is possible to evaluate the variables of tone reproduction, thereby enabling you to exercise greater control over your results. The principle of tone reproduction analysis can be applied to optical systems, other than cameras, wherever flare light is present or wherever changes in exposure and choices of material are possible.

Exercises (820):

1. Before starting a graphic analysis of the tone reproduction, what conditions must you consider in making a preliminary analysis of your problem?

2. If there was no flare light in the system and if the negative and positive were exactly matched, what would you expect to find in the tone reproduction curve?

3. Why does the position of the reproduction in figure 2-15 indicate that the reproduction is dark?

4. What causes the situation shown in curves 5 and 6 in figure 2-16, C?

5. What other systems can the principle of tone reproduction analysis be applied to?

821. Explain the following three things: (1) the value of an original negative, (2) the value of tone reproduction diagrams, and (3) the effects usually present in the negative.

Duplication of Negatives. In the field of extreme high altitude reconnaissance, the original negative is a priceless item. It is acquired only through careful planning and at great expense. Furthermore, the information it contains may be of such a nature that it can never again be obtained. Therefore, it seems wise to go to great lengths to protect this negative. If a good master positive is made from this original, any number of duplicate negatives may be produced from it. These duplicates are used to produce the necessary prints, and the original negative can be preserved.

While these duplicates are being made, the utmost control must be maintained so that little or no loss of intelligence occurs. As a matter of fact, resolution can sometimes be improved by putting the film through several generations of reproduction. Tone reproduction diagrams are of considerable value in controlling the processing of multiple generations of film, just as they are of value in the production of positives from negatives.

In the process of negative duplication, the effects of camera flare and of atmospheric haze are already present in the negative to be duplicated, and it is necessary to include them in the tone control diagram. This is comparatively simple if the log luminance of the terrain objects are known; but if you have nothing except the finished negative, it becomes involved. The first step would be to plot a D log H curve of the negative material in block 1 of your tone reproduction diagram. Then, using a densitometer with a narrow look angle, read the maximum and minimum densities in the negative. Correlate these densities to the negative curve, as shown in figure 2-17. Curve A is the D log H curve of the negative material, and point e represents the minimum desired negative density corresponding to the minimum scene luminance. Point a is the measured minimum density in the negative and would occur at point f on the negative material curve. It is placed on the ordinates above point e. Point d, the measured maximum negative density, is placed to correspond to the maximum desired scene luminance density. Thus, we have established the limits of the log BS_0. The limits for the log IS_i will be between points f and d, and by inserting the calculated values into equation

$$BS_0/IS_i$$

a usable flare factor (FF) for this condition can be obtained.

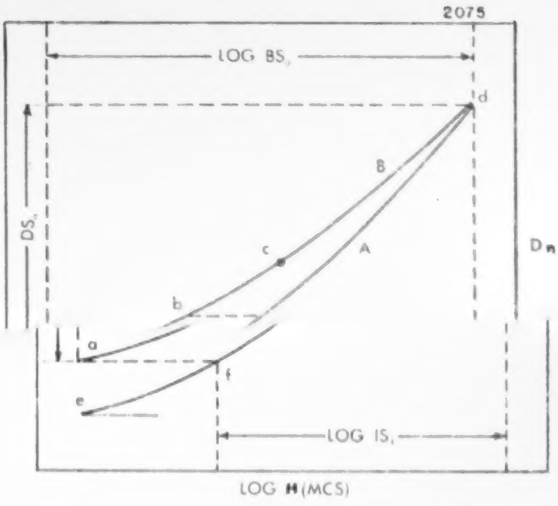

Figure 2-17. Correlation between negative density and log luminance of ground objects.

Once the negative curve is derived, you would select the films needed to produce the master positive and the duplicate negative. To obtain the desired density differences in the reproduction, the duplicating materials should be selected with care. From here on, the reproduction diagramming procedures are routine as long as prints are made by contact. However, if projection printers are to be used, additional blocks (diagramming the flare characteristics of the printer) must be inserted in the appropriate places on the reproduction cycle diagram.

Exercises (821):

1. Would you consider the original negative to be a priceless item? Explain.

2. Of what value are tone reproduction diagrams?

3. In the process of negative duplication, what are usually present in the negative?

822. Identify and explain the exposure and processing parameters that must be computed for negative duplication, and in given problems, identify the specific necessary requirements.

Single Block Tone Reproduction Control. Using the principles discussed in the preceding paragraphs, a procedure for controlling the duplication of already exposed and developed original negatives has been developed. This procedure, which is known as trigradient tone reproduction, uses the tones present in the original negative as a basis for computing the exposure and processing parameters of negative duplication.

The trigradient system. In the classical system, flare conditions in the camera and haze conditions in the scene are plotted so that their relationship to the negative and positive materials can be seen. Since the trigradient system is designed to be used for duplication of negatives through several generations, a calibrated step wedge is used to represent the original negative. Figure 2-18 illustrates the way brightness values are recorded by a photographic system.

The subject reflects light values (levels of brightness) which the film sees as variations in light intensity. The film, upon being exposed and suitably processed, yields density values which vary according to the levels of brightness: the greater the brightness value, the greater the resultant density. Although rendition is proportional in the middle of the negative scale, it is compressed at either end, thereby lessening detail discrimination in those areas. Moreover, compression might also exist in all areas due to atmospheric attenuation of brightness values.

The slope of the curve is determined by the nature of the negative material and the development it received. If a "perfect" negative could be produced, the response of the scene brightness values would be one for one, as shown in figure 2-19.

A comparison of the two figures readily shows how tonal response is altered. The curve in figure 2-18 has the same gradient in the straight-line portion as seen in figure 2-19. The compression occurs because of shoulder and toe characteristics of negative materials. By the judicious selection of photographic material, the response of a given input can be compressed, held constant, or even expanded within reasonable limits. This is true whether you are photographing an original scene or working from an already exposed and developed negative.

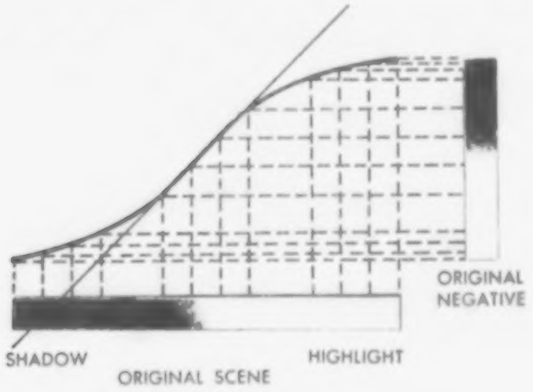

Figure 2-18. Typical response scene brightness values on a negative having a gamma of 1.00.

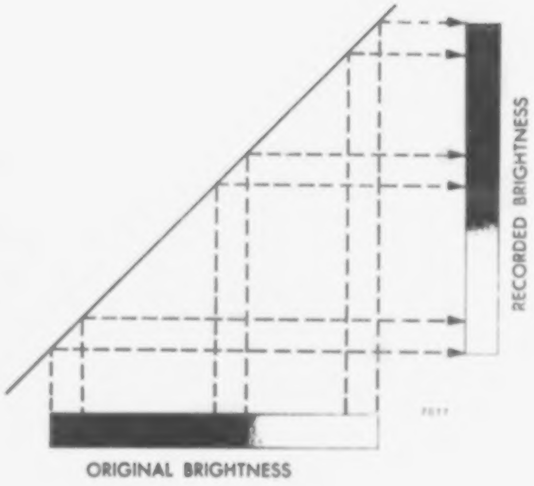

Figure 2-19. Response of scene brightness values on a "perfect" negative having a gamma of 1.00.

In reproduction of images initially recorded on a photographic film, the laboratory has three criteria: (1) to reproduce the full scale of the original subject, or as much as was recorded on the initial exposure; (2) to provide tonal compression due to inadequacies of the original recording medium; (3) to provide an increase in informational capacity through an appropriately customized reproduction system.

Figure 2-20 illustrates an original scene compressed somewhat when recorded on a negative. Printing this negative on a film to retain normal to wide density difference (Δ D) as the next step in duplicating it will fulfill the first criterion if the range of tones in the negative is not too great. It will not entirely fulfill the second criterion and will not satisfy the third criterion at all. The conditions shown here are satisfactory where the original scene consists of a normal range of tones with adequate discrimination between them, but cannot correct for tonal compression or expansion.

In a scene with a low brightness range, such as the one shown in figure 2-21, where there is little discrimination between tones, the wanted tones can be placed on the straight-line portion of the negative. Then, printing the negative on a material capable of delivering a high gamma results in an expansion of the density differences.

The scene represented in figure 2-22 has a normal brightness range. The negative should be printed to maintain the range of density differences.

The scene represented in figure 2-23 contains a wide brightness range and requires processing to a low gradient so that the range of tones can be accommodated on the straight-line portion of the printing material. The delta density of the reproduction is compressed by this treatment. A comparison of the output Δ D of the three illustrations shows that they are all very near to each other. Thus, both short-scale and long-scale scenes can be improved through

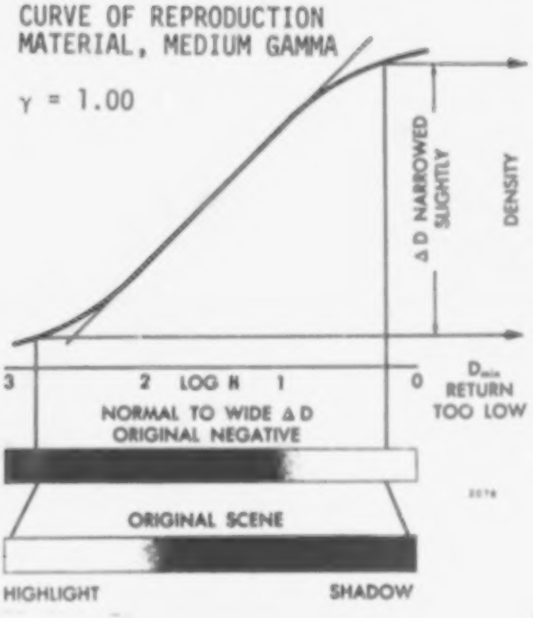
CURVE OF REPRODUCTION MATERIAL, MEDIUM GAMMA
γ = 1.00
Δ D NARROWED SLIGHTLY
DENSITY
3
2
LOG H
1
0
Dmin RETURN TOO LOW
NORMAL TO WIDE Δ D ORIGINAL NEGATIVE
2078
ORIGINAL SCENE
HIGHLIGHT
SHADOW

Figure 2–20. Normal to wide density difference (ΔD).

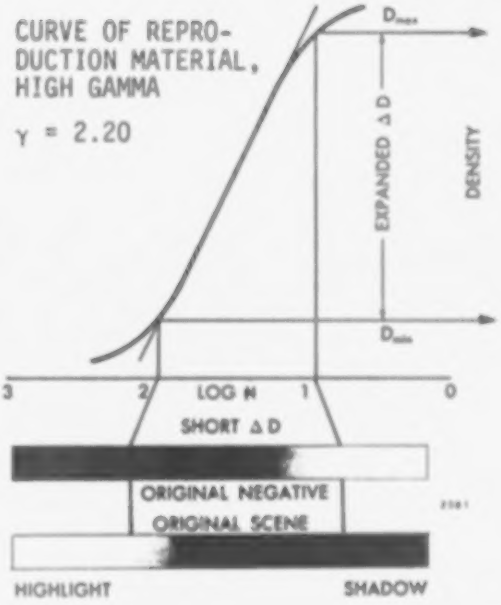
CURVE OF REPRODUCTION MATERIAL, HIGH GAMMA
γ = 2.20
Dmax
EXPANDED Δ D
DENSITY
Dmin
3
2
LOG H
1
0
SHORT Δ D
ORIGINAL NEGATIVE
ORIGINAL SCENE
2081
HIGHLIGHT
SHADOW

Figure 2–21. Short ΔD.

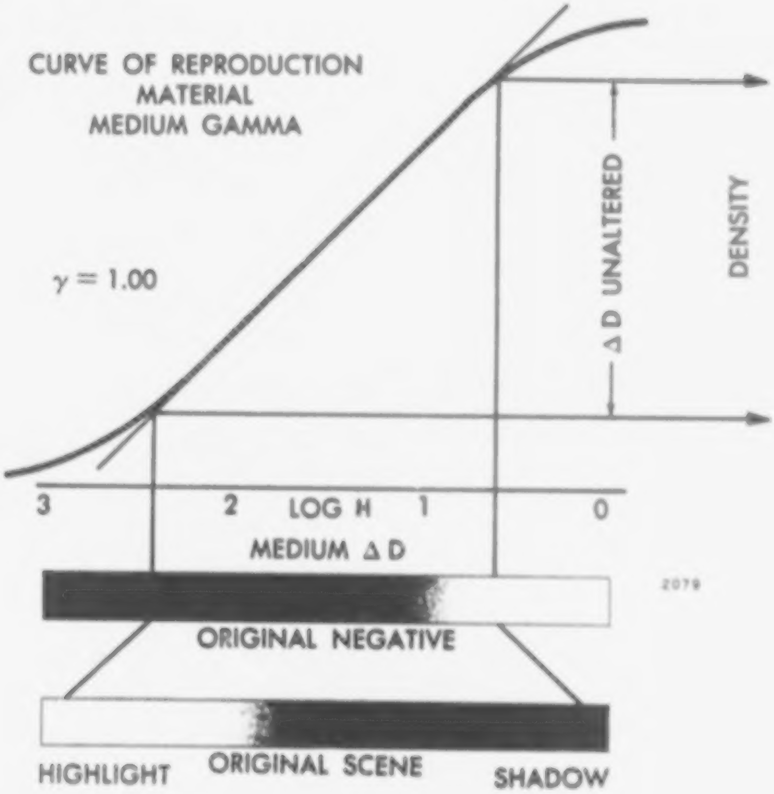
CURVE OF REPRODUCTION MATERIAL MEDIUM GAMMA
γ = 1.00
Δ D UNALTERED
DENSITY
3
2
LOG H
1
0
MEDIUM Δ D
2079
ORIGINAL NEGATIVE
HIGHLIGHT
ORIGINAL SCENE
SHADOW

Figure 2–22. Medium ΔD.

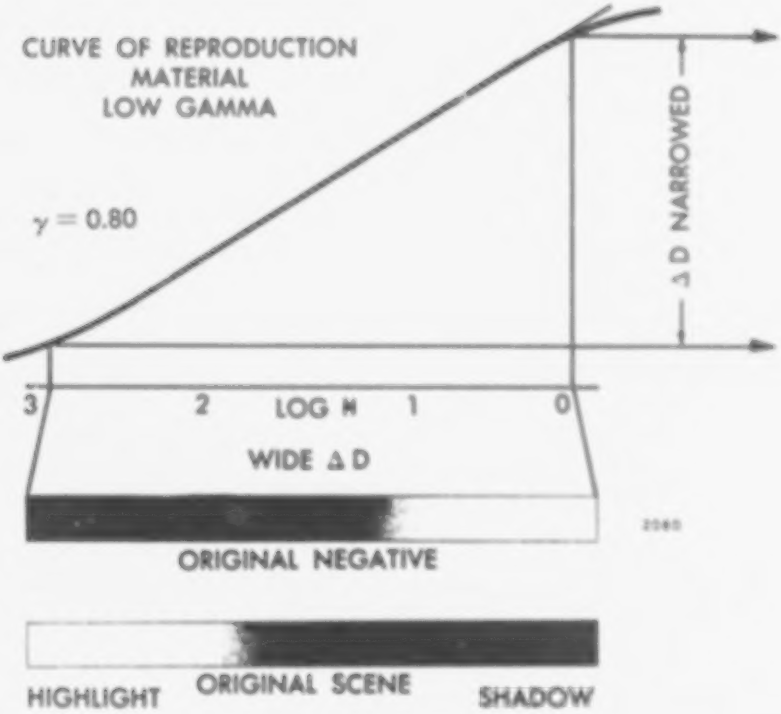

Figure 2-23. Wide ΔD.

the appropriate choice of material and printing and processing techniques.

Emulsion evaluation. The initial step in preparing trigradient tone controls is to determine the sensitometric characteristics of the emulsion to be used. You can do this by constructing an H and D curve for each material; but, instead of gamma, an average gradient ($\overline{G}$, called bar gradient) between the densities 0.30 and 1.80 is taken (fig. 2-24). High-contrast material should have a $\overline{G}$ from 1.50 to 1.70; the $\overline{G}$ of medium-contrast material should lie between 0.95 and 1.05; and low-contrast material should produce a $\overline{G}$ between 0.85 and 0.95. The processing machine to be used is certified, and a family of tone reproduction curves for each emulsion is prepared.

Curve construction. To produce the tone reproduction curves, a calibrated step wedge is placed in the printer to be used in the system, and a series of controlled exposures is made. In certain printers, such as the ''Niagara'' or the ''Concord,'' the exposure may be controlled by varying the voltage of the light source, by changing the printer speed, or by changing the intensity of the light. To obtain maximum control, it is good practice to eliminate as many variables as possible. Ideally, any two variables should be stabilized while the third is used to control exposure. Practically, a variable such as light intensity is controlled by means of filters of various neutral densities. In figure 2-25, there are 12 exposures shown, starting with the maximum (zero neutral density) and attenuated by increments of 0.10 neutral density. These exposures were made and plotted as a family of curves. The curves in the figure are medium tone reproduction curves having a $\overline{G}$ of 1.0. The same procedure can be used to produce a family of curves for high- and low-tone reproduction response. Preparation of these sets of curves involves reading and plotting 12 sensitometric strips for each material used. This is a long and tedious process. Laboratories producing large quantities of work generally use an automatic recording densitometer, such as the ''Quantascan'' shown in figure 2-26, and accomplish this task in minutes rather than in hours.

After plotting the curves, set all of the data pertinent to the running of the strips on the chart. This data should begin with the date that the operation was performed, should show the emulsion number, and should include all of the printing and processing parameters. You should show the relative, log exposure on the base line as progressing from right to left to relate it to the densities of the step wedge from which the curves were derived.

Validity of curves. Logically, the next step is to ascertain whether or not the family of tone reproduction curves is valid. You can do this by taking hypothetical densities and applying them to the curve. For example, let us assume that we are dealing with a maximum density (D_{max}) of 1.98 and a minimum density (D_{min}) of 1.30. The delta density for these

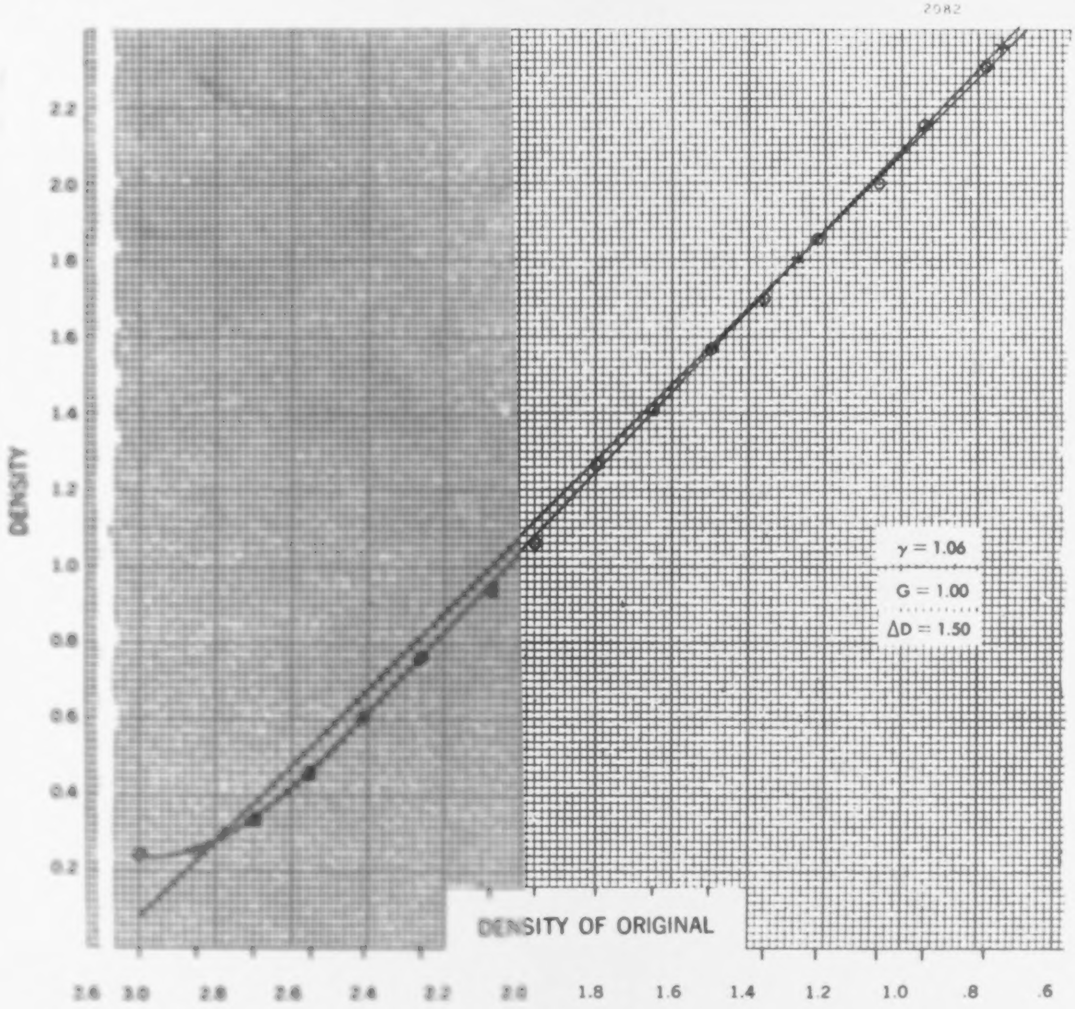

Figure 2-24. G of an emulsion.

conditions is 0.68. Taking the acceptable minimum density in the reproduction to be 0.35 above base plus fog, or approximately 0.40, arbitrarily set this value as the desired D_{min}. Because the printing light must pass through these densities, maximum density in the negative should correspond to the desired minimum density in reproduction. Therefore, find 1.98 on the baseline and move up the ordinate to that point where it intersects a curve at a density of 0.40. Then, find 1.30 on the baseline and trace up the ordinate to where it intersects the curve just selected. Now, trace across the abscissa to find the density value at this intersection. In this case, assume that it is 1.24. The value of ΔD is the difference between 0.40 and 1.24, which is 0.84. This means that the set of high tones has been expanded from 0.68 to 0.84, indicating that this set of curves will perform as expected. This procedure is repeated for each set of medium- and low-tone reproduction curves. Now, you are ready to use your sets of curves for actual process control.

Process control. The control over negatives to be duplicated requires that the input densities be taken directly from the roll of film to be duplicated. The roll is scanned over a viewer for uniformity of contrast and density throughout the roll. Assuming that it is uniform, it is examined to find its D_{max} and D_{min} range.

Determining delta D. To select the D_{max} and D_{min} of a roll of negatives, some special equipment is required. We need a light table equipped with rewinders for moving the film across an illuminated and gridded viewing screen as well as a densitometer that can be moved into place to make density

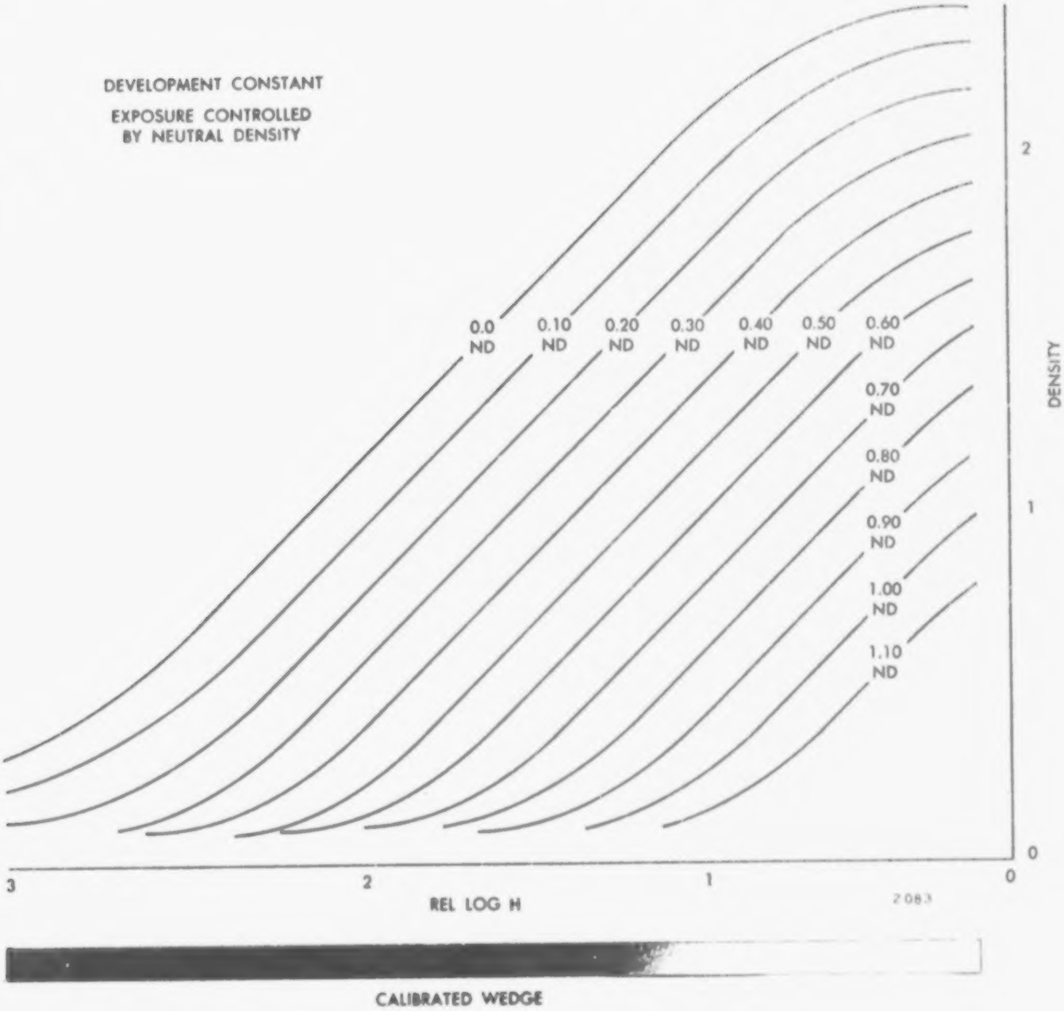

Figure 2–25. Typical medium-tone reproduction curves.

readings. Mobility of the densitometer should be such that it can be removed while the film is being transported. Figure 2-27 displays a table of this type.

The viewing screen of the light table is ruled into squares, with the spaces between the lines numbered in one direction and alphabetized in the other. Thus, a density can be located by placing it in a square having a unique letter-number designation. For instance, in negative 22 of roll 6, the D_{max} might be 1.95 in H–14 and the D_{min} might be 0.60 in B–11, etc. Because densities in a negative might occupy small areas, the densitometer should operate with an aperture of 0.50 mm. If the spot size of a densitometer is reduced from that which is originally supplied, the intensity of the light source must be increased to compensate for the smaller aperture.

The roll is passed across the table, and individual negatives are selected at random. The negative number is recorded, and its image is examined for maximum and minimum densities. The densities selected should be good photographic densities, ignoring specular highlights and clear areas. The D_{max} and D_{min} are recorded together with the negative number, and the process should be repeated a number of times until you are satisfied you have located the actual D_{max} and D_{min}. It is the actual, not the average, densities you want. However, at the same time, carefully avoid taking an excessive density; i.e., one that lies outside of the normal range. While this selection can be done mathematically by evaluating a great many densities and running a statistical determination, with experience, you can do it by visual examination and exercising good judgment.

Once satisfied that the correct D_{max} and D_{min} have been determined, find the Δ D by taking the difference between the two. The Δ D indicates which set of tone control curves

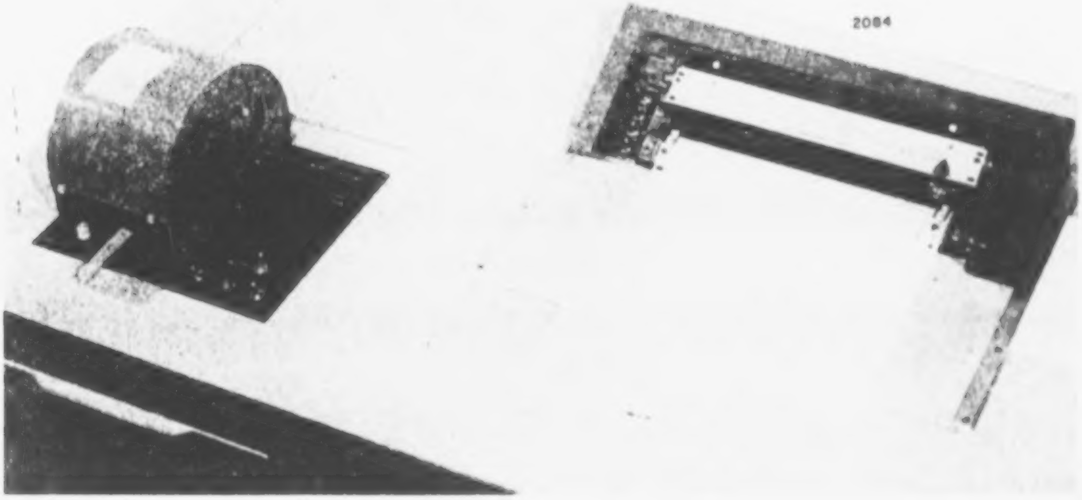

Figure 2-26. An automatic recording densitometer.

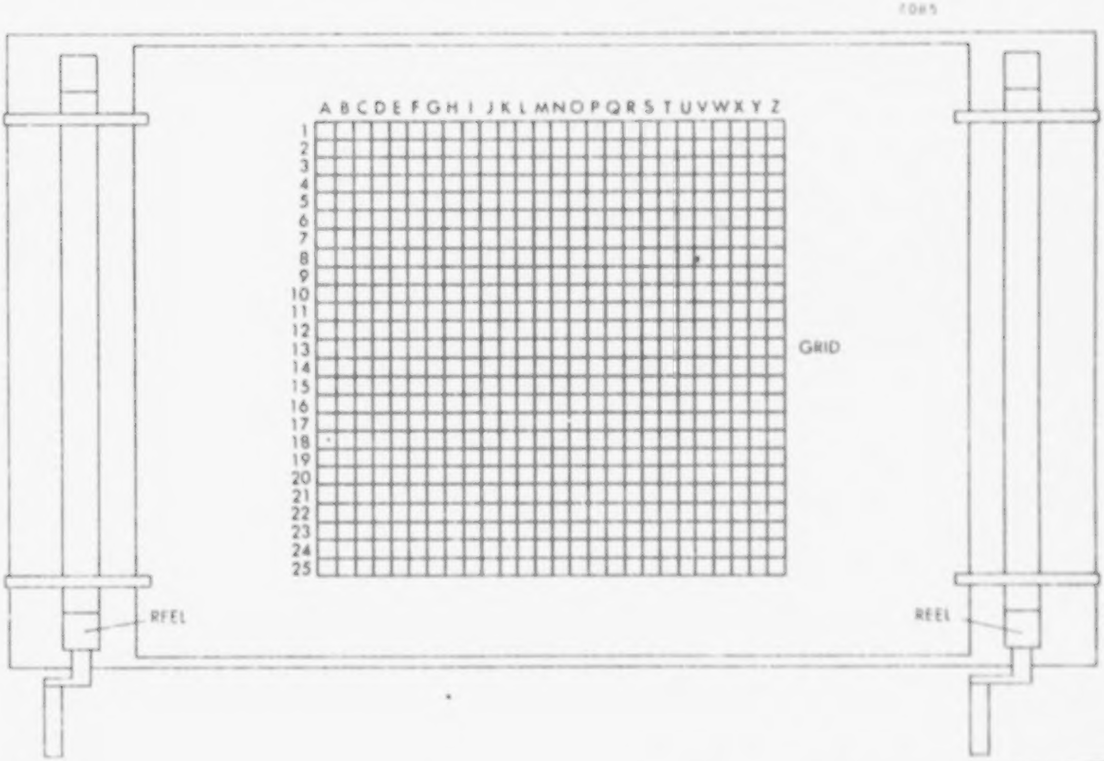
2085
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
GRID
REEL
REEL

Figure 2-27. A viewing table with the graded light screen.

(high, medium, or low) should be consulted for printing instructions. Figure 2-28 illustrates how the low-tone control curves appear.

Printing instructions. Suppose, now, that your delta determination showed a D_{max} of 2.00 and D_{min} of 0.60, and that D is 1.40. This is higher than the upper limit of our 0.80 to 1.15 range; therefore, it is necessary to compress the tonal scale. Obviously, the set of low gradient tone control curves must be consulted.

By referring to figure 2-28 (the low gradient tone control curves), D_{max}, 2.0, is located on the relative log exposure line and then traced upward on the graph to the density 0.40. In this instance, the intersection occurs midway between the curves produced by 0.10 and 0.20 neutral density in the printer. This indicates that to obtain the desired output density, you must use 0.15 neutral density in the printer.

The printing instructions should show the following:

- The negative number.
- The location of the selected D_{max} and D_{min}.
- The numerical values of D_{max} and D_{min}.
- The numerical value of the Δ D.
- The type of film to be used.
- The exposure to be given.

Development, of course, is always held constant.

A suitable form for issuing and recording printing instructions is necessary, and one should be developed by the using agency to meet their particular requirements. The printing instructions should set down on the form and should accompany the film throughout its process, including the sensitometric evaluation of the finished film. When the printing instructions are to accompany the negative and film into a superclean laboratory, the form must be printed on some lint-free substance that will not contaminate the environment of the laboratory. Moreover,

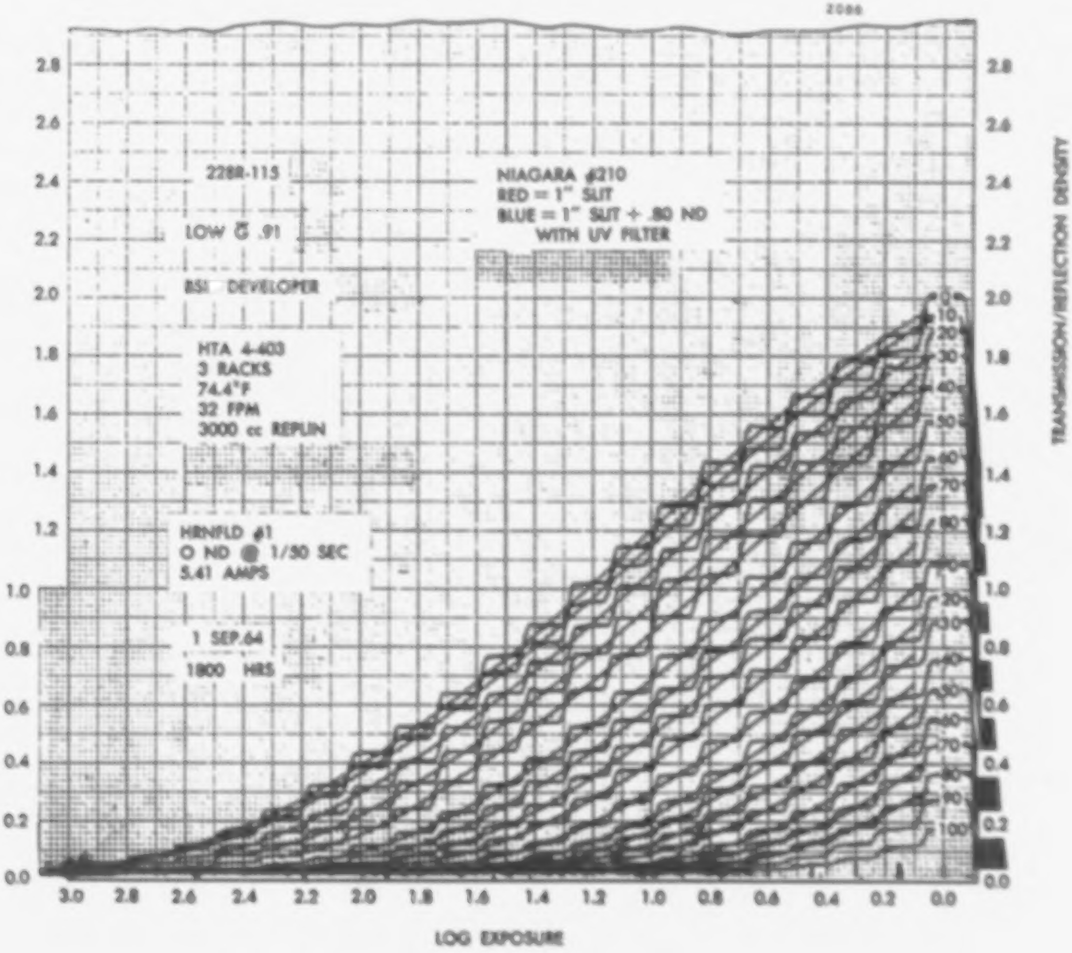

Figure 2-28. Low tone control curves.

the instructions must be written on the form using a stable ink—not pencil—since the latter can introduce contamination that could seriously impair the quality of the work.

To continue with our example, let us assume that the processing is done in accordance with the instructions. The master positive, produced from the original negative, is then examined on the viewing table, and the selected D_{min} and D_{max} values are measured and recorded. Suppose that the return density for the original D_{max} is the new D_{min} 0.42 and the return density for the original D_{min} is the D_{max} 1.57, the Δ D for the master positive is 1.15. This is the absolute upper limit of the Δ D range. At this point, there is a decision to be made—either accept this range and hold all subsequent generations to it or elect to compress the scale still further to place it in the middle of the range. In either case, the procedure requires you to select and apply the appropriate set of tone reproduction curves and to issue the appropriate printing instructions.

Although the control procedure is the same regardless of the number of generations of reproduction, the original set of tone curves should not be used beyond the second generation. The reason for this limiting action is that various emulsions and bases transmit light to varying wavelengths of the spectrum; therefore, if the spectral composition of the light is altered by the film base, then the reproduction will be affected. This effect is multiplied by each succeeding generation and, ultimately, the response will be totally unpredictable. To be on the safe side, a new set of tone reproduction curves should be made at the third generation. To do this, select a second generation wedge that most nearly allows you the number of steps required for full tone reproduction. By using it as the calibrated wedge, construct a new set of tone reproduction curves. These curves then become the basis for issuing printing instructions for succeeding generations. This practice is repeated whenever necessary, depending upon the number of generations required.

Monitoring sensitometric parameters. When carried out in accordance with printing instructions, the processing run is valid only if conducted according to the same procedures under which the original tone reproduction diagrams were drawn. To be certain of this, frequent monitoring is necessary. This is why controlled step wedges must be inserted into the production run at frequent intervals, and H and D curves and tone reproduction curves drawn.

Any change in the sensitometric parameters should immediately result in a corresponding change in the printing instructions. A variation in any portion of the system—a change in the developer, in the time of development, the temperature of the solutions, or in the printer speed—may necessitate changing the tone reproduction curves. Even the simple act of replacing a lamp in a printer requires that a check be made to determine whether or not the tone reproduction curves are still valid.

If the checking procedure indicates only slight shifts in response, compensatory measures may be taken. For instance, a minor addition or subtraction of neutral density in the printer may be sufficient to shift the curve back to its desired position. But, if the deviation is excessive, an entirely new set of tone control curves must be made.

Control stock. Because sensitometric characteristics of emulsions vary not only from batch to batch but within emulsion batches, a control stock is set aside so that uniform tests can be conducted. A control stock is one that most nearly meets the requirements imposed on the process by the laboratory. The control stock is normally kept under critical storage conditions so that it is not subjected to unpredictable occurrences that could change its sensitometric characteristics.

Whenever a new lot of raw film is received, it is sampled immediately and compared to the control stock. That portion of the newly arrived raw film which most nearly matches the present control stock is set aside as the new control stock. However, it is good practice to sample the entire lot and make a listing of any deviations from the present control stock. As a result, you can select the film from stock which meets the requirements of almost any job.

Exercises (822):

1. What is the basis for computing the exposure and processing parameters of negative duplication?

2. In the trigradient system, how is the original negative represented?

3. If a "perfect" negative could be produced, what would the response of the scene brightness values be?

4. In the reproduction of images recorded on a photographic film, what are the three criteria available to the laboratory?

5. Referring to exercise 4 and figure 2-20, printing this negative on a film to retain normal-to-wide density differences (Δ D) will fulfill what criterion?

6. Figure 2-21 shows little discrimination between tones. What printing material would be needed to expand the density differences?

7. The scene represented in figure 2-23 contains a wide brightness range and requires what kind of processing?

8. What is the initial step in preparing trigradient tone controls?

9. When constructing an H and D curve for each material, what do you use instead of gamma?

10. To reproduce the tone reproduction curves, what is placed in the printer?

11. Laboratories producing large quantities of work generally use what kind of a machine in the preparation of the sensitometric strips?

12. What is the reason for limiting the original set of tone curves up to the second generation?

13. When monitoring the sensitometric parameters, when do you consider that the processing run is valid?

823. Identify the information the multiple block system provides, and identify the starting point for the trigradient system.

Multiple Block and Trigradient Systems. The multiple block system, with its four quadrants, can provide solutions to tone control problems. When all information needed to plot quadrants I and II is available, the results plotted in quadrant II are used as a starting point. This, then, is also the starting point for the trigradient system. Advantages of using the trigradient system lie in the fact that it allows for a certain flexibility and a reasonable amount of accuracy when predicting a return for a given density input.

By this time, you have probably noted that the trigradient system uses the same basic approaches, except that the curves used to determine density returns are compared generations of the original H and D curves. When reproduction beyond the second generation is necessary, you can use a specific set of tones made with the aid of a second generation step wedge instead of a calibrated wedge; so the same procedures for obtaining positive tone controls can be applied to negative tone controls. Positive and negative tone controls can be used to solve practically any reproduction problems that you may encounter.

Exercises (823):

1. When all information needed to plot quadrants I and II is available, what does the multiple block system provide?

2. What is the starting point for the trigradient system?

824. State the purpose, list the steps, and identify negatives used for mosaic printing.

Mosaic Quality Prints. A mosaic is composed of two or more aerial photographs pieced together to give the illusion of a single photograph. Mosaics are assembled in two formats, strip and area cover. A strip mosaic is an assembly of overlapping prints from a single flight pass. An area cover mosaic is an assembly of side-lapping strip mosaics. Generally, a mosaic is produced from the vertical sensor, thereby minimizing distortion. They can also be made from other sensors to produce a panoramic effect, but with increased distortion.

Mosaics fall into two classes—uncontrolled and controlled. The uncontrolled mosaic is constructed simply by the assembly of the photographs, matching corresponding images (detail matching). This method is a rapid means of producing a composite picture of areas where relative, rather than absolute, positions of the terrain features are desired. The controlled mosaic is constructed from photographs altered through rectification printing. During actual assembly, these photographs are aligned to very precisely plotted control points.

Controlled mosaics are primarily used for map and chart revision and as map substitutes. Due to the time and accuracy involved in constructing a controlled mosaic, it is normally prepared by cartographers and mapping personnel.

A mosaic can be used to supplement conventional maps which often do not show recent changes, such as new roads, bridges, dams, etc. The prime use of mosaics in intelligence is for briefings and as attachments to reports.

Preparation. Before actual production of the mosaic begins, several steps must be taken. First a photo index must be prepared. (See fig. 2-29.) A photo index is a rough assembly of aerial prints made from the negatives exposed on a reconnaissance or mapping mission. The photo index is prepared by first removing the borders from the prints. The prints are then assembled by matching the detail in the center portions of the overlapping print areas.

NOTE: Do not attempt to match detail in the border areas, as it will probably not match due to distortion.

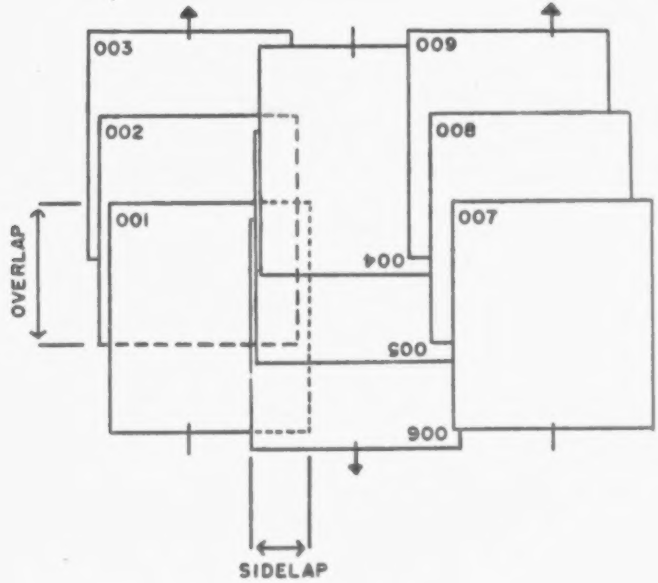

Figure 2-29. Photo index.

The prints for the photo index are quickly assembled in sequence by the use of staples. This assembly shows:

a. Whether the desired area has been adequately photographed. This is called "coverage." If the coverage is incomplete (that is with gaps, called "holidays," between flight passes), it may be necessary to re-fly the mission.

b. The percentage of overlap and sidelap. (See fig. 2-29.)

(1) Overlap is the identical coverage that is contained in consecutive frames from a single flight pass. Ideal overlap is 60 percent of the imagery.

(2) Sidelap is the identical coverage that is contained in different flight passes over adjacent areas. Ideal sidelap is 30 percent of the imagery.

c. Which print, lying near the center of the strip, will be selected as the master print. Master prints will be discussed later.

d. Roughly the overall size of the mosaic to be laid.

The second preparation step is to procure a sufficient amount of photographic paper to print the entire mosaic. During the manufacture of paper emulsions, different batches will vary slightly in characteristics. For this reason, you should obtain enough single-weight glossy paper of the same emulsion number to complete the mosaic printing job. Base your calculation of the requirement on three sheets of paper for each negative to be printed. Such a computation will allow for unavoidable damage in addition to a pair of prints for each negative.

Third, you must procure a sufficient amount of photographic developer to complete the mosaic. As in the case of emulsions, stock-developing solutions mixed at different times may not have consistent characteristics. Therefore, you should complete an entire mosaic printing assignment with developer that was mixed at one time. You should figure on 16 ounces of developer for the first 20 prints and 12 ounces for each additional 20 prints. One and a half gallons of mixed, diluted developer are good for about 100 prints. This may seem like an unusually large quantity, but you must remember that overworked, exhausted developing solutions will change the tone of the prints, making it impossible to match them to the master print. It is for this reason that developer is discarded after the aforementioned number of prints have been processed.

NOTE: Oxidation, caused by prolonged exposure to air, will also alter a developing solution. Discard the developer at the end of one hour, regardless of how little it has been used.

Master print. Most areas photographed for a mosaic are large enough to include many different features of terrain and manmade objects. Since the diversity of the scene could produce negatives of widely varying contrast and density, it is necessary to examine all the negatives of a mission to select the one that is most representative of the entire mission. This negative is used to make the "master" print with which all other prints will be matched. The master print must have maximum detail in all areas, normal or slightly less than normal contrast, and a uniform tone and density.

NOTE: The intensity of the printer lights should be adjusted so that the master print requires a minimum exposure of 5 seconds. It is very difficult to obtain consistent results when exposure times are too short, even though the printer is equipped with an automatic timer. To ensure full detail, develop the master print for at least 1 minute.

though the printer is equipped with an automatic timer. To ensure full detail, develop the master print for at least 1 minute.

Printing. Printing negatives for mosaic assembly is much the same as making prints for other purposes. Prints are made on single weight glossy paper—not on waterproof or resin-coated papers. Examine the negative to determine the basic exposure time and any dodging needed. A gradually changing negative density may sometimes require that the basic exposure be changed as the job progresses. Uniform tone and density are vitally important if the mosaic is not to have an unpleasant patchy or checkerboard appearance. The achievement of this quality takes a little more care than is normally used in manual printing. The key to success is the master print.

Processing. There is a difference in the way mosaic prints are processed compared to normal manual processing. Again, the key to success is the master print.

After the wet master print has been thoroughly fixed and washed, place it on the bottom of an inverted tray near the developer so that other prints can be matched to it. As a print dries, it changes tone slightly; therefore, you must keep the master print wet by frequent splashings of water. Depending on mission requirements, you always make at least two prints of each negative just in case the mosaic assembler damages one.

Disregard continuous timers when you are developing prints to match the master print. Obviously, when another print matches the master print, it has received the correct amount of development no matter how long it has taken. The degree of development greatly affects the tone of a print, and the amount of exposure governs the length of time it must be developed to produce a given density. As a result, it is extremely important that each print receive the correct exposure. For example, an appreciable amount of overexposure will cause a print to reach the density of the master print in a short developing time, but development time will give the print a much different tone. Hence, while it will match in density, it will not match in tone.

Develop the prints in pairs (back-to-back) so that they get exactly the same amount of developing time. When they appear to be approaching the tone and density of the master print, remove them from the developer, rinse them briefly in a water stop bath to retard developing action, and compare them with the master print. If the prints have not yet reached the proper density and tone, return them to the developer for additional processing. Discard prints that have been permitted to develop to a greater density than that of the master print.

NOTE: The action of fresh developing solution falls off quite rapidly after the first few prints are made, after which time it becomes quite stable. Since stability of action is essential to the production of mosaic prints, you must stabilize or "ripen" each batch of developer working solution. Ripen the first quantity of working solution by fully developing eight sheets of fogged paper in 1 gallon of developer. Ripen the succeeding solutions by mixing a half gallon of the old used developer with each 1 gallon of fresh developer.

Mosaic prints are fixed for the usual length of time; however, you must give them special attention to make sure that they receive sufficient agitation to prevent stain. If a print becomes stained because of lack of agitation, duplicating it at a later time may be very difficult. It is a good policy to agitate all the prints in a fixing bath every time additional prints are added. Washing time is 30 minutes in running water.

NOTE: Often in mosaic printing a double fixing bath is used to insure complete fixation. The prints are left in the first fixing bath for half the required fixing time. They are then transferred to the second fixing bath to complete the fixation. The first bath becomes exhausted sooner than the second. When this happens, the first fixing bath is removed, the second bath is moved into its position. Fresh fixing bath is then placed into the second position. This is the ideal arrangement, space permitting.

Drying. The manner in which prints are handled when assembled into a mosaic requires that they be soft and pliable. The application of heat tends to make them brittle as well as to cause a shrinkage which distorts the image dimensions, thus affecting the scale match between individual prints and adjacent flight passes. Controlled mosaic prints are not dried in a drum-type, heated dryer. Rather, they are soaked for five minutes in a 10-percent solution of glycerin, then air dried, either by placing them emulsion side down on cheesecloth stretched across racks or between blotters.

Exercises (824):

1. What is the purpose of an uncontrolled mosaic?

2. State the purpose of a controlled mosaic?

3. List the steps used to prepare for mosaic printing.

4. What is the ideal percentage of overlap and sidelap needed for mosaic prints?

5. What are the requirements of a "master print?"

6. What is used to control development of mosaic prints?

CHAPTER 3

Photographic Effects

THE PHOTOGRAPHIC effect is the result of complex chemical and physical processes that occur during exposure and processing. In order to acquire a workable understanding of it as a whole, we must try to understand its parts. We will discuss some of the characteristics of latent image formation to start with, and then move on to some of the seemingly abnormal effects which have puzzled photographers and photographic scientists for many years.

3-1. The Law of Reciprocity Failure

There are presently no rules to which reciprocity failure can be generally related to emulsion characteristics such as speed, grain size, or color sensitivity; therefore, the reciprocity effect must be determined for each different combination of characteristics inherent in the emulsion in question.

825. State one way to graphically represent the effects of reciprocity failure.

Reciprocity Failure Curves. There are several ways to represent graphically the effect of reciprocity failure. One is to give the emulsion a series of reciprocally varied constant energy (I × T) exposures. That is, exposures are changed thus: IT = 16 × 1, 8 × 2, 4 × 4, 2 × 8, etc., and the variations obtained through this treatment are analyzed. A more extensively used method consists of plotting families of constant density curves based on the log IT vs. log I. Figure 3-1 illustrates typically reciprocity failure curves made by this method. Characteristic reciprocity failure curves are usually symmetrical for a considerable range in the vicinity of their minimum point, but often take an abrupt upward turn at the low intensities. The exposure intensity of maximum efficiency is the value producing a medium density within the range of 0.1 to 10 seconds. Except for slight deviations in optical density, the time of development has little effect upon the shape of the curve.

Exercises (825):

1. How would you graphically represent the effect of reciprocity failure?

826. State the emulsion characteristics that are affected to the greatest extent by reciprocity failure.

Interpretation of Reciprocity Failure Curves. The emulsion characteristics that are affected to the greatest extent by the law of reciprocity failure are speed and contrast, and these are among the more important emulsion characteristics to workers in all fields of photography. By means of reciprocity failure curves, which chart a series of densities, you can obtain the values of these factors for both intensity-scale and time-scale H and D curves within the range of intensity covered by the reciprocity curves. Also, the way in which these factors vary with intensity is apparent enough to show the general trend, enabling you to apply the information to practical photographic exposures. The curves shown in figure 3-1 are typical. They represent density values of 0.5, 1.0, 1.5, and 2.0, and cover a range of intensity values from one to one million.

The first step in reading the reciprocity diagram is to locate the lines of constant intensity and the lines of constant time. (Note that the constant-intensity lines are representative of time-scale H and D curves and that the constant-time lines correspond to intensity-scale H and D curves.) Any vertical line on the reciprocity diagram is a constant-intensity line, and any 45° line is a constant-time line. Tracing a vertical line upward would produce the same density-log IT values as those which would be met while proceeding upward along a time-scale H and D curve. In fact, you can plot an H and D curve from the density vs. log IT values obtained from the points where a vertical line intersects each of the density curves. Also, gamma can be computed directly from the reciprocity curve by dividing the density differences between the two curves by the vertical intercept in log IT units between the two curves. This is an application of the formula

$$\gamma = \frac{\Delta D}{\Delta \log IT}$$

where

γ = gamma
D = density difference
log IT = log intensity times time difference

As in all gammal computations, the density values selected must both be on the straight-line portion of the characteristic curve.

In figure 3-1, the lines of constant time are shown by the 45° lines. Proceeding upward along one of these 45° lines,

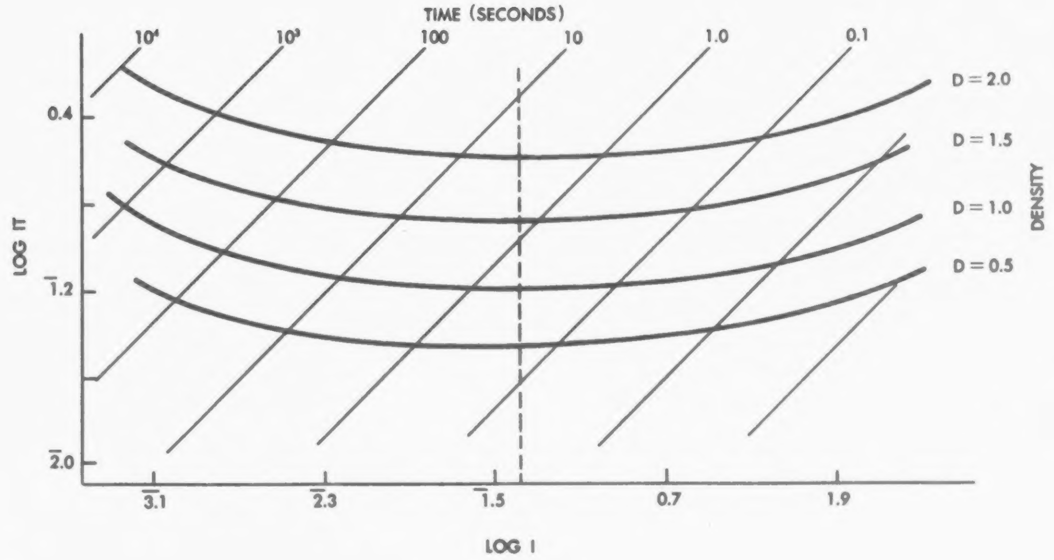

Figure 3–1. Reciprocity failure curves.

you would encounter the density-log IT values corresponding to those in an intensity-scale H and D curve. Dividing the density differences between two reciprocity curves by the log IT differences as read from the points where the constant-time line intersects the reciprocity curves will produce the gamma. For example, on the 100-second constant-time line in figure 3-1, the density difference between D = 1.5 and the D = 1.0 curves is 0.5. The corresponding lot IT difference read from the intersection points is 0.31; therefore, applying the above equation and substituting the appropriate values, we have

$$\gamma = \frac{0.5}{0.31} = 1.61$$

Thus the gamma of this curve is 1.61.

The comparative curves in figure 3-2 will illustrate the differences existing between time-scale and intensity-scale exposures. Three sets of curves were plotted from the values of the reciprocity diagram—one being near optimal intensity, one well above, and one well below optimal intensity. The intensity-scale curves were derived from the 1000-second, 1-second, and 0.01-second lines; and the time-scale curves were derived from the 0.0012 mc, and 0.312 mc, and the 80 mc intensity lines of figure 3-1. The below optimal curves show the intensity-scale curve is the steeper of the two, and the ratio between curves is 1.60 to 1.20. With exposures of optimal intensity, the two curves are nearly alike, having a ratio of 1.35 to 1.25 for the intensity-scale and time-scale curves, respectively. In the above-optimal curves, the slopes of the curves are reversed from those in the below-optimal chart. The ratio is now 1.25 for a to 1.00 for b. Notice that the time-scale curves did not change very much while the variation in the intensity-scale curves was from 1.60 to 1.00 in this experiment. We can see from this that the intensity-scale curves tend to conceal it. This seems to indicate that when time-scale sensitometers are used in exposure tests, it is necessary to know the reciprocity failure characteristics of the emulsion being tested in order to interpret the results and apply them to practical situations.

Exercises (826):

1. What emulsion characteristics are affected to the greatest extent by reciprocity failure?

3-2. Effects of Reciprocity Failure

In the past, the effect of temperature on reciprocity was mainly of scientific interest, since most photographers operated within a rather limited temperature range. But since the advent of ultrahigh altitude reconnaissance, temperature—particularly low temperature—must be considered.

827. Explain the effects of temperature on reciprocity failure.

Effects of Temperature on Reciprocity Failure. The variation in reciprocity failure due to temperature changes over a range of from 50° C to −186° C is shown in figure 3-3. At high intensities, the log IT value increases as the temperature decreases. At low intensities, the log IT value decreases as temperature decreases until a minimum is

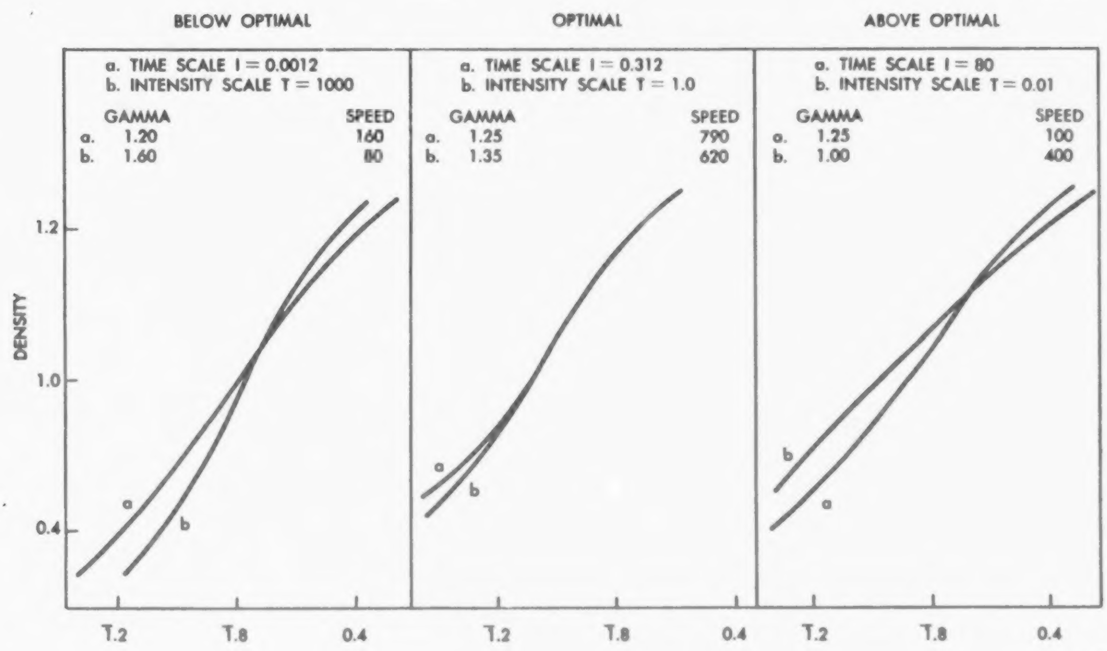

Figure 3-2. H and D curves derived from reciprocity failure curves.

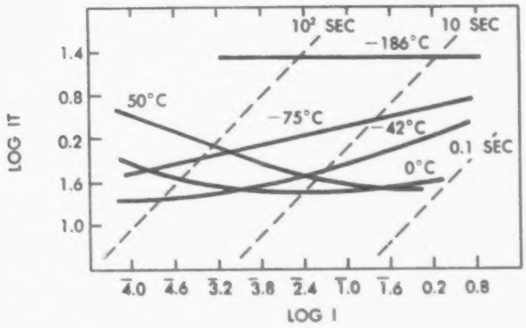

Figure 3-3. Effects of temperature on reciprocity failure.

reached and then increases. Thus, the sensitivity of the emulsion to light of low intensity increases at first with decreasing temperature and continues until temperatures somewhat below 0° C are met. This phenomenon is useful when it is necessary to make long exposures to low-intensity light sources. By lowering the temperature of the photographic material, shorter exposures would be required.

Looking at figure 3-3, we can see that there is virtually no reciprocity failure at −186° C; however, at this temperature, long exposures would be required to offset the loss of sensitivity.

Exercises (827):

1. How do temperature changes affect the log IT values of the emulsion?

2. Of what value is this phenomenon of low temperature to the ultrahigh altitude reconnaissance mission?

828. State the effect of wavelength on reciprocity failure.

Effect of Wavelength on Reciprocity Failure. Exposing an emulsion to light of various constant wavelengths shows a rather uncomplicated reciprocity failure variation. If reciprocity curves for various wavelengths are drawn as shown in figure 3-4, the curves will be quite similar in shape, but will be displaced parallel to each other along the 45° constant-time lines. The curves will exhibit the characteristic response to changes in intensity unchanged by differences in wavelength. This suggests that the spectral sensitivity of an emulsion is not dependent upon exposure time.

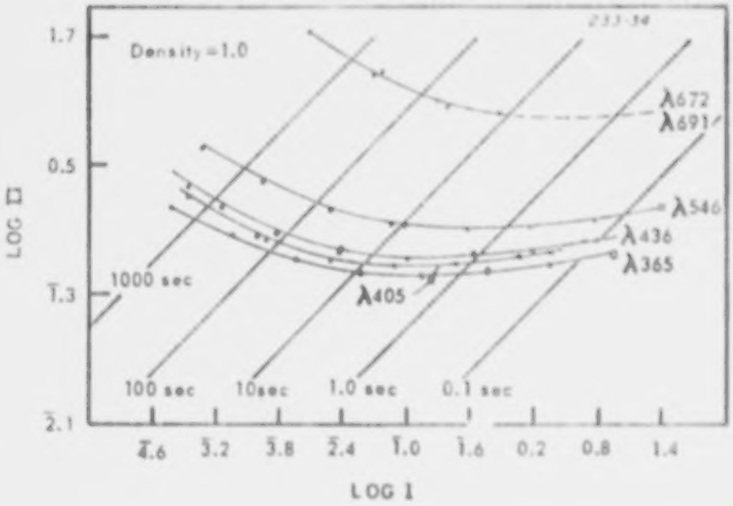

Figure 3-4. Effects of wavelength on reciprocity failure.

All photographic emulsions exhibit the effects of reciprocity failure, but they are serious at very high or very low illumination levels. In aerospace photography, the emulsion is troubled by reciprocity law failure (1) when exposing film in extreme heat or cold, since reciprocity failure varies with temperature; (2) when using deep cutting filters, since reciprocity varies with wavelength; and (3) when exposing multilayer or color film because of variations between emulsions.

Exercises (828):

1. Exposing an emulsion to light of various constant wavelengths shows what kind of a reciprocity failure variation?

2. In aerospace photography, when is an emulsion troubled by reciprocity failure?

829. Explain the effects of color reversal film on reciprocity failure.

Effects of Color Reversal Film on Reciprocity Failure. The three emulsions of color film are usually not the same in composition and are expected to have different reciprocity law characteristics. Figure 3-5 shows that color shifts are more of a problem than changes in overall speed and contrast. The constant density lines represent layers of cyan, magenta, and yellow dyes. The three different film layers require balancing so that their reciprocity failure characteristics are similar over an extended range of exposures between approximately 1/10 to 1/1000 second. Where exposure times are longer than 1/10 of a second, adjustment is made to the exposure given each of the three emulsion layers. This is done by adding the proper color filter and increasing the level of exposure. If the film represented in figure 3-5 had an ASA speed of 64, the speed rating would be valid over the 1/10 to 1/1000 second range. Going outside of this range, the film would require more exposure and a lower ASA speed rating.

Exercises (829):

1. Why does color film have a greater complexity problem in reciprocity law failure?

2. Where exposure times are longer than 1/10 of a second, what adjustments must be made to the exposure?

830. Explain how the intermittency effect is closely related to reciprocity failure.

The Intermittency Effect. Closely associated with reciprocity failure is the "intermittency effect." When an exposure to a series of intermittent units of light is given, the resultant density is different from that which would be produced by a continuous exposure of the same energy. Abney, in 1893, conducted a series of experiments investigating the effects of light intensity, ratio of light-to-dark periods, and the speed of interruption of exposure. He found that in every case, the intermittent exposure produced

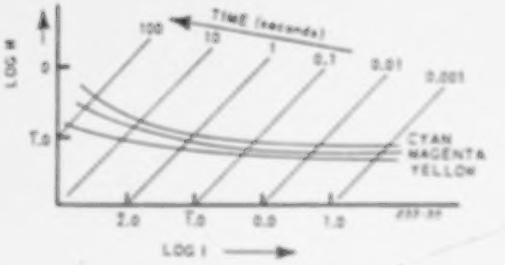

Figure 3-5. Reciprocity law failure for reversal color film.

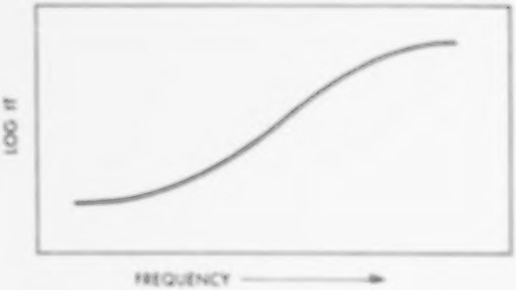

Figure 3-6. Intermittency effect as a function of flash frequency.

a smaller photographic effect than a continuous exposure of equal energy. Later in 1899, Englisch made further studies of the intermittency effect and his findings supported those of Abney. He found also that the intermittent exposure was dependent upon the intensity and amount of light in each flash and the rate of interruption. Then, in 1900, Schwarzschild reported that an intermittent exposure always produces a lesser effect than its corresponding continuous exposure.

Later investigations into the nature of intermittent exposures disclosed that: (1) for very low flash frequency, the results are almost equal to the effect of an equal-energy exposure; (2) a long exposure broken into a large number of interruptions produces an effect equal to that of the continuous exposure; (3) increasing the frequency of the flashes causes an increase in the exposure required to equal the continuous exposure until the frequency of flashes is high enough to approach the effect of the quanta randomly hitting the halides during a continuous exposure; and (4) the effect produced by an intermittent exposure occurs between the effects produced by two continuous exposures. Figure 3-6 illustrates graphically the intermittency effect as a function of flash frequency.

Exercises (830):

1. Why is the intermittency effect closely related to reciprocity failure?

2. Investigations into the nature of intermittent exposures disclosed that a long exposure broken into a large number of interruptions produced what effect?

Evaluation of Color Processes

MUCH OF WHAT has been discussed in previous paragraphs on sensitometry can be considered as carryover training toward understanding color sensitometry. However, color sensitometry is much more critical than sensitometry used on conventional black-and-white film, particularly since the color balance of the exposing light as well as the emulsion present must be considered.

4-1. Color Sensitometry

In the laboratory, you can correct (within limits) exposure deficiencies by using filters during the printing process, utilizing the concepts dictated by color sensitometry. But because the structure of color materials is more complex than that of black-and-white materials, more steps and procedures are needed for you to make color sensitometric evaluations and to establish control. As with black-and-white sensitometry, you should begin color sensitometric procedures with a series of controlled exposures on color film, measuring these exposures with a color densitometer and recording the results in graphic form. Just as in black-and-white sensitometry, inferences drawn from color sensitometry enable film manufacturers to make uniform products, assist photographers to select optimal exposures, and allow laboratory personnel to exercise precise control over color processing.

831. Identify the approaches and state the procedures for sensitometric testing of color materials.

Sensitometric Exposures. In color sensitometry, the first and foremost requirement of the sensitometric exposure is that the exposure should be about the same as found in the actual subject exposure. Because of the complex structure of color emulsions, the variability of the dyes and color formers, and the vast number of spectral energy distributions present in the scene being photographed, it is difficult for you to measure, much less control, all of the parameters of color reproduction. Therefore, to be practical, sensitometric evaluation of color materials is based upon gray-scale exposures. Such exposures are made by using sensitometers designed specifically for the purpose or by black-and-white sensitometers that have been modified.

Light source. Usually the basic light source for sensitometers is a tungsten lamp that operates at 2850 K and a photometric filter (such as the Wratten 78AA series) that is used to raise the color temperature of the light to approach daylight. While this combination provides a good visual match to daylight, its spectral energy distributions vary too much from daylight to be used for exposing color materials. A better filter to use with tungsten lamps is the Corning glass 5900 filter, or, if the specifications of ANSI Standards (PH 2.11–1958, PH 2.20–1960, PH 2.21–1961) are to be met, the Davis-Gibson liquid filters should be used. Both glass and liquid filters are more stable than comparable gelatin filters, but even they tend to change their absorption characteristics with changes in temperature. Also, liquid filters have been known to leak after a time.

It is comparatively simple to provide light sources both for use in sensitometers and for tungsten light color photography. All that is required is that the two sources have the same spectral quality. But it is another matter to test color films for use with electronic flash or fluorescent light. For one thing, there is no known combination of tungsten lamps and filters that will provide comparable light sources. However, a sensitometer that uses an xenon gas-filled flashtube works very well in these spectral ranges.

There are two principal approaches to the sensitometric testing of color film. In one, exposures are made through sharp-cutting filters so that one layer of the film is exposed at a time. In the other, all three layers are exposed simultaneously to yield a neutral response when viewed together. When sharp-cutting filters are used, their density reduces the exposing light to the degree that the exposures required are much longer than normal. Extending exposure times tends to aggravate the reciprocity failure characteristics of the color film. Therefore, the illuminance at the film plane should be increased sufficiently to permit exposures which conform to actual practice. The illuminance may be raised by increasing the wattage of the lamp, raising the operating temperature of the lamp, or moving the lamp closer to the exposure plane. All of these methods present heat dissipation problems, and the last also produces an exposure that diminishes in intensity at the extreme ends. Curving the exposure plane so that all parts of it are equidistant from the source overcomes this fault.

Exposure modulators. An ideal exposure modulator might be one which employs the inverse square law to produce attenuated light for the required series of exposures. But such a device would occupy a great deal of space and would be cumbersome to use. For practical use, a step wedge makes the best light attenuator. Since so much care must go into their manufacture, good step wedges are expensive. They may be either carbon (colloidal graphite) or photographic wedges, just so they are nonselective

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between wavelengths of 350 nm and 700 nm. That is, the absorption of radiation passing through the wedge should be the same for all wavelengths of light. In testing multilayer film, the densities produced by any one step in the separate layers may not vary from the next step by more than 0.02 or 1.5 percent (whichever is greater). The entire range of densities of normal color film should extend from almost zero to about 3.0, in increments of 0.15. (Some color print films may have a shorter range of densities.) The change in exposure with distance along the modulator for either continuous or stepped exposures should not exceed a factor of two per centimeter. For stepping increments, the exposure increment should not be greater than a factor of 1.5874, or $\sqrt[3]{4}$ per step.

Because adjacency effects may seriously impair the uniform density developed in the sample being tested, the size of the patches in the wedge should be comparatively large. Patches of not less than 0.5 cm in the smallest dimension will give satisfactory results.

Monitoring the semsitometer. To comply with the ANSI Standard PH 2.11–1958, the use of the Taylor-Kerr spectral-energy distribution chart appended to that document is recommended for sensitometrically exposing daylight color film. However, other color materials have other requirements, and you should always remember that the exposure given should correspond to those obtained in actual practice.

Records of the performance of the sensitometer must be diligently kept. These should include records of the operating time and records of periodic measurements of illuminance level. Changes in the spectral quality of the light source may be detected by taking periodic readings with a photoelectric photometer through sharp-cutting primary filters. If these records are set down in a type of control chart, significant changes can be seen at a glance; and appropriate action can be taken before any appreciable damage is done. Once your control procedures have been established, keeping your operation functioning within your limits of acceptance is simply routine.

Exercises (831):

1. Sensitometric evaluation of color materials is based on what type of exposure?

2. How can the basic tungsten light used in a sensitometer be modified?

3. What are the two principal approaches to the sensitometric testing of color film?

4. What is the basic requirement of either a carbon or a photographic wedge when it is used as an exposure modulator?

5. When maintaining records for the performance of a particular sensitometer, what two items should you enter into them?

832. Explain the extent of the variability in sensitometric color processing.

Processing the Test Strips. The image produced by the development of a controlled sensitometric exposure is governed by the characteristics of the material being tested and the nature of the process to which the material is subjected. Both of these factors are variable. If you desire to evaluate one of them, the other must be held constant. Therefore, to study the variations arising out of changes in exposure, the sensitometric process should be one that is constant and not subject to the changes met in a production situation. Also, to evaluate changes in processing resulting from day-to-day operation or to learn the differences between several processing machines, the sensitometric exposure should be closely controlled and made on a reference emulsion.

The necessity to minimize variability in sensitometric color processing is much greater than in black-and-white sensitometry. In the latter, development byproducts diffuse laterally within the single layer; whereas in the former, diffusion also occurs vertically from one emulsion layer to another. Thus, vertical adjacency effects can occur which will change the density and quality of the image. In black-and-white processing, adjacency effects are minimized by giving the film sufficient agitation during development to permit free outward diffusion of byproducts. But how do you cope with diffusion of byproducts between the layers of color film? You are limited to controlling such parameters as: the chemical composition of the solutions, the mixing procedures, the time of development, the temperature of the developer, and the drying cycle. As a result, you are compelled to accept the effects over which there is little or no control.

The processing solutions must be mixed with the utmost care. The rate at which dry chemicals are added to water should not vary from mix to mix. Extreme cautions must be taken to avoid introducing air into the solution during mixing. When mixed, chemical solutions are stored away from light, in full bottles, and never for periods greater than their recommended shelf life. Keep solutions cool during their storage, but not so cool as to cause precipitation of their ingredients.

While the quality of the processing solutions may be checked by chemical analysis, such methods are neither economical in time nor money, nor are they sufficiently accurate to warrant doing them. It is possible to weigh the ingredients that go into a solution much more accurately than their quantities can be determined by chemical analysis. A carefully exposed and processed sensitometric strip will show up discrepancies in the solutions. However, while the results of a sensitometric test indicate that an error may be present, they do not necessarily disclose the source of the trouble.

Controlled sensitometric processing to test film characteristics is frequently carried out in specially designed processing machines. These machines are usually much smaller than production-type equipment and thus are limited to a small amount of work. Their size permits using quantities of solutions small enough to be discarded after each use, thereby eliminating the effect of solution deterioration from continued use. Furthermore, sensitometric developing machines can maintain the desired processing temperature to closer tolerances and hold the degree of agitation to the desired level. Agitation in processing machines of this type is provided by circulating the solution, by stirring devices mounted in the processing tanks, by sets of oscillating vanes moving past the surface of the film, by bursts of inert gas introduced into the tanks, or by combinations of these.

Agitation is highly critical in sensitometric processing; and when testing for processing control, agitation must conform to practice through all stages of the process, since minor changes in agitation can have pronounced effects on the developed image. When monitoring an imagery production facility, sensitometric strips are attached to all incoming film included in the regular production run.

To determine the extent of variability in an imagery production facility, it is first necessary for you to accumulate a certain amount of data. Sensitometric strips should be processed in various parts of the tank and at various times during the processing day. This is done over an extended period of time so that all characteristics of the process, based on statistical evaluations, are determined and control procedures can be established.

Exercises (832):

1. Why is the diffusion of developer byproducts so critical in a color emulsion?

2. Is it feasible to check the quality of the processing solution by chemical analysis? Explain.

3. Why is agitation highly critical in sensitometric processing?

4. To determine the extent of variability in an imagery production facility, what must the technician accumulate?

4-2. Measuring Color Densities

After processing, the sensitometric tests become developed film samples consisting of series of small patches, uniform in color, which are the result of precisely controlled exposures. Each part is, in effect, a filter with absorption characteristics resulting from the exposure and development given and from the characteristics of the film being tested. From these patches, you can derive certain information about the exposure, development, and film characteristics. All of this can be done by measuring light absorption characteristics of the various areas. The type of measurement used must, of course, depend upon the information being sought. If you are interested in the total effect of the three superimposed layers, measure integral densities. If you are concerned with the absorption characteristics of the individual layers, then measure the analytical densities.

833. Identify the two general classes of color densities, name two major divisions of color densities, and list subdivisions under each division.

Kinds of Color Densities. Color densities are sometimes divided into two general classes. The particular class of density being read depends upon the type of instrument used to measure it, as:

- Specular densities, measured by collimated light through an aperture which accepts only the undeviated light.
- Diffuse densities, measured by a receiver which accepts all of the nearly collimated light passing through the sample, or by a receiver with a small aperture which measures light transmitted by the sample.

Color Densities According to Purpose. Classifying color densities according to purpose is meaningful and widely used. The two major divisions are:

- Integral densities, where the total effect of the three superimposed dye layers is measured.
- Analytical densities, where absorption of each dye layer is measured separately.

Both major divisions may be further subdivided into the subgroups shown in figure 4-1.

Integral densities. Under this heading, the subdivisions are defined as follows:

a. Printing densities measure the effect of a transparency or negative on specific print material, using a specific printer.

b. Colorimetric densities can be used to predict the effect obtained when the color image is examined visually. The responses are the component colorimetric responses of a standard observer.

c. Luminous densities are similar to colorimetric densities, except that their measurements are in terms of luminosity responses of a standard observer.

d. Three-filter densities merely compare samples with standards. These densities do not indicate any particular

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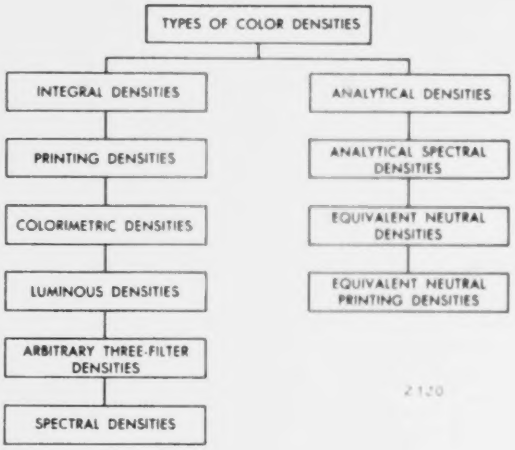


Figure 4-1. Types of color densities.

film use, nor do they indicate the nature of the image. The filters used are arbitrary red, green, and blue filters; and the response depends entirely upon the kind of evaluating device used. These measurements are usually limited to processing control.

e. Spectral densities measure the wavelength-by-wavelength absorption of the color image. Such measurements are usually made on a spectrophotometer or a similar device capable of providing narrow-band radiation.

Analytical densities. The subdivisions under this division are defined as follows:

a. Analytical spectral densities (ASD) require the measurement of absorption of each dye layer using monochromatic radiation. The amount of dye present is described as a spectral density at a particular wavelength.

b. Equivalent neutral densities (END) identify each dye by a single number defined as the density of the visual neutral formed by the dye sample when appropriate amounts of the remaining two dyes are added to it.

c. Equivalent neutral printing densities are defined in the same manner as equivalent neutral densities, except that the printing emulsion, instead of the dye, is the receptor.

Exercises (833):

1. What are the two general classes of color densities?

2. When classifying color densities according to purpose, how would you list two major divisions?

3. List the subdivisions under the heading "integral densities."

4. List the subdivisions under the major division "analytical densities."

834. Identify factors which determine light absorption characteristics, and from given information, calculate light absorption characteristics of color densities.

Colorants. For a thorough understanding of color sensitometry, it will be profitable to study some of the physical (optical) principles which affect the characteristics of transparent colorants. For example, the action of the cyan, magenta, and yellow dyes in subtractive color film is to modulate the red, green, and blue light. This modulation depends upon the absorption characteristics of the dyes; therefore, the amount of light absorbed by a dye is directly proportional to the number of absorbing molecules in the dye. The more absorbing molecules that are present, the greater is the probability that light will be absorbed. The more light that is absorbed, the greater is the density of the medium to light. The absorbing properties of a medium may be increased either by increasing the concentration of molecules in a given thickness or by increasing the thickness of a medium of a given concentration.

Beer's law. The absorption of a medium involving relative concentrations of molecules is governed by Beer's law, which states that for a constant thickness, spectral density is proportional to concentration. Thus:

$$D\lambda = a \lambda c$$

where

$D\lambda$ = special density
$a'\lambda$ = the absorption coefficient for unit concentration and any constant thickness
c = the concentration of the absorbing molecules

This action is shown diagrammatically in figure 4-2 where a medium having a density of 0.40 transmits 40 percent of the incident light, while the same medium whose density is increased to 0.80 transmits only 16 percent of the incident light.

Bouguer's or Lambert's law. Increasing the thickness of a homogeneous medium (fig. 4-3) reduces transmission according to Bouguer's law, which can be stated:

$$D\lambda = a' \lambda d$$

where

$D\lambda$ = spectral density
$a'\lambda$ = the absorption coefficient for the unit thickness and a constant concentration. (This is a wavelength variable.)
d = thickness

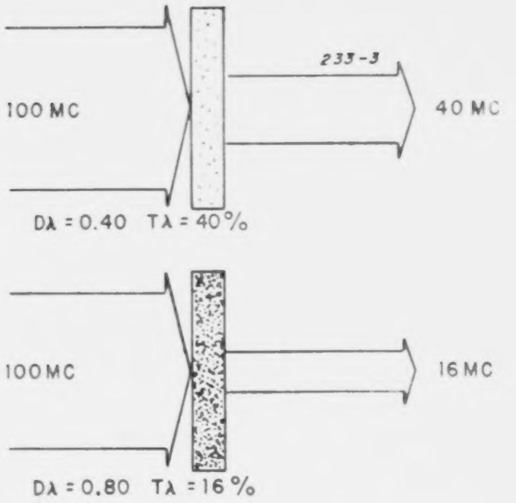


Figure 4–2. Beer's law.

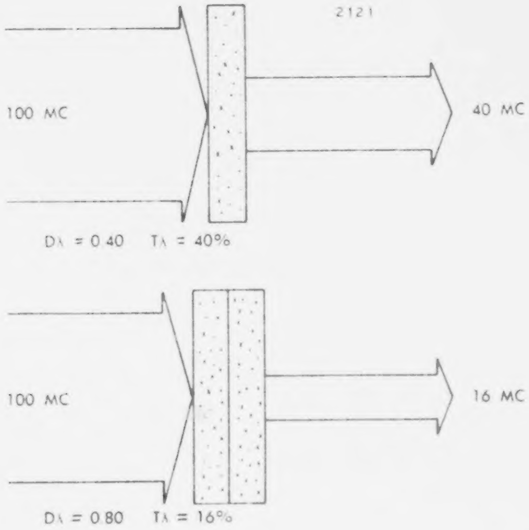


Figure 4–3. Bouguer's law.

Bouguer's law, also known as Lambert's law of absorption, says that for a transparent colorant of constant concentration, the spectral density is proportional to the thickness of the medium.

Lambert-Beer law. The combined effect of thickness and concentration is described by a combination of the two previous equations, thus

$$D\lambda = A\lambda dc$$

where

$A\lambda$ = the absorption coefficient for both unit thickness and unit concentration.

To clarify these equations, look at figure 4-4, which illustrates the relation of the incident light, the transmitted light, the concentration, and the thickness of the medium. Since density, D, is the common logarithm of the reciprocal of the transmittance, it can be expressed as:

$$D = \log_{10}\left(\frac{1}{T}\right)$$

where

$$T = \frac{I}{Io} \text{ or } D = -\log_{10}\left(\frac{I}{Io}\right)$$

or

$$D = \log_{10}\left(\frac{Io}{I}\right)$$

Beer's law and the Lambert-Beer law hold true when:

- Light of a single wavelength is used.
- The medium is homogeneous.
- Only the light transmitted through the medium is measured.

Light due to fluorescence, scattering by suspended particles, or inefficiency of the measuring instrument will invalidate your results.

Additivity rule. If several dyes are combined, the spectral density of the mixture should be equal to the sum of the spectral densities of each dye. In figure 4-5, the density of the neutral gray curve is seen to be the sum of the densities of the yellow, magenta, and cyan curves.

Proportionality rule. For dyes which obey Beer's and Bouguer's laws, it is found that the ratio of spectral densities at different wavelengths is constant, regardless of the concentration. If the concentration of a dye is changed, the density of that dye at one wavelength varies proportionally with its density at all other wavelengths. For

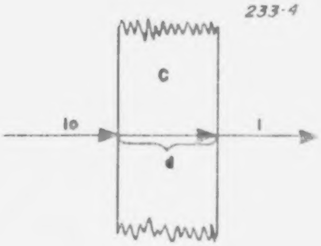


Figure 4–4. Relationship of incident and transmitted light.

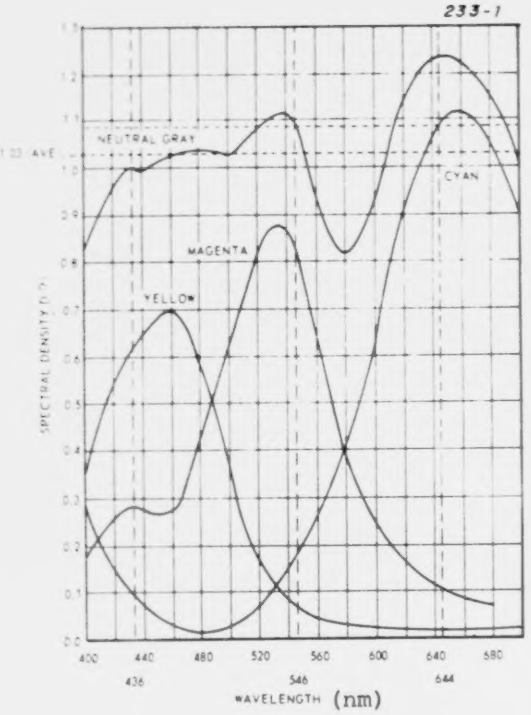


Figure 4–5. Spectral densities of neutral gray and component colors.

example, if a given dye has spectral density of 1.50 at 450 nm and 0.80 at 650 nm, the ratio is 1.50/0.80 = 1.87. If the concentration was increased to give a spectral density of 1.85 at 450 nm, the spectral density at 650 nm is $\frac{1.85}{x}$ = 1.87, since the ratio is constant. Solving for x, we find that the spectral density of 650 nm is approximately 0.99. By following these procedures, the ratios for any pair of wavelengths can be calculated.

Log D rule. The proportionality rule can also be stated as the log D rule, thus:

$$\text{Log } D\lambda' - \text{Log } D\lambda \ (2) = k$$

This equation indicates that if curves are plotted log density vs. wavelength, they will have a constant shape, regardless of concentration. Referring to figure 4-6, you can see that the three curves are quite parallel, and since the concentrations differ by a factor of 4, all of the densities must differ by the same factor. When the logs of the densities are taken, the spacing between the curves is the log of 4 or 0.6 for all wavelengths.

Exercises (834):

1. In color materials, what actually determines the amount of light modulation of a particular color?
2. When modulation of a single color is solely dependent on the number of dye molecules (or concentration), which of the laws and rules would be used to determine absorption properties?
3. Situation: Assume that the following spectral densities have been measured: y = 0.35, m = 0.18, c = 0.30. Given these measurements, what would be D λ of the corresponding END be?
4. Situation: Using the proportionality rule, the initial Dλ of a given dye at 480 nm is 1.45 and 0.75 at 680 nm. Based on these figures, what concentration would be at 480 nm if the concentration at 680 nm were decreased to measure Dλ = 0.69 and the ratio remains constant?
5. Using the values for the initial Dλ given in exercise 4, how would you set up the equation under the log D rule?

4-3. Color Density Measurement Instruments

Before resuming our discussion of color densities, it seems appropriate that we examine some of the devices used for measuring color densities. Because the measurement of color densities requires that very narrow bands of spectral energy be isolated, color densitometers need to be more sensitive than those used for routine black-and-white measurement. Also, the fact that densities of 3.0 or more are not uncommon in color transparencies further supports the requirement for higher sensitivity.

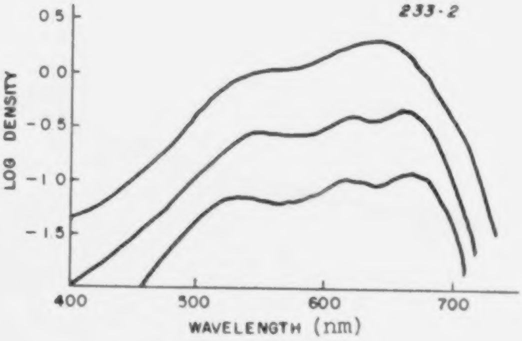


Figure 4–6. Characteristic curves of a dye image.

835. Explain how to select an illuminant to measure color densities.

Illumination. The first requirement of an illuminant by which color densities can be measured is that adequate energy is furnished in the desired wavelength bands and that the illumination remains uniform over extended periods of use. In production instruments, constancy of output is generally assured by using voltage regulators and by operating tungsten lamps below their rated voltage.

Illumination produced by tungsten lamps is deficient in the short wavelengths but abounds high in infrared. The situation necessitates using filters to compensate for the spectral condition and heat dissipators to reduce the effects of infrared (IR) radiations. For purposes of standardization, the use of a mercury-cadmium arc lamp as the energy source for color densitometry is recommended. The mercury-cadmium arc has the advantage of having a substantial part of its output peaking at the approximate centers of three of the principal spectral regions; i.e., 436, 546, and 644 nanometers. Although mercury-cadmium arcs are more efficient in the desirable spectral regions and do not generate much heat, they are not suitable for practical densitometry and are, therefore, considered to be mainly laboratory standards.

Exercises (835):

1. Why must the illumination of a color densitometer usually be modified?

2. For purpose of standardization, what energy source for color densitometry is recommended?

836. State the primary purpose of using filters in an integral densitometer and one of the more important requirements of such a color densitometer; list the filters most frequently used in integral densitometers.

Filters. The purpose of the filters used in most integral color densitometers is to limit the spectral composition of the illumination to the narrow wavelength bands required for special measurement. Although the use of certain standard filters is prevalent, you should realize that both color-positive and color-negative films vary in the absorption peaks of their dyes. The color densities of a particular film read on one densitometer cannot be compared directly with the densities read on another densitometer. However, readings from different densitometers can be correlated mathematically.

The filters most frequently used are a red filter with a dominant wavelength of about 646 nm, a green filter whose wavelength peaks at 545 nm, and a blue filter with a dominant wavelength of 460 nm. (In the Wratten series, these filters are numbered 92, 93, and 94, respectively.) All of these filters transmit in the infrared; therefore, a densitometer using them should also be equipped with an IR-absorbing filter, such as a dichroic filter.

One of the more important requirements for the filters used in color densitometry is that they should be stable. They must be able to withstand the heat, humidity, and radiant energy to which they will be subjected in the densitometer and still retain their spectral characteristics. Glass filters are the most stable and should be used whenever possible. However, it is sometimes necessary to use gelatin filters, even though they have obvious weaknesses—they are fragile. Because they are fragile and are easily fingermarked, gelatin filters should be handled only by their edges. By their very nature, gelatin filters are hydrophilic, and moisture tends to cloud them. Also, heat causes them to soften; so temperatures above 120°F must be avoided. To preserve them, the gelatin filters must be stored under cool, dry conditions. Gelatin filters should be inspected frequently and discarded when they show signs of deterioration.

Exercises (836):

1. What is the primary purpose of using filters in an integral densitometer?

2. What is one of the more important requirements for filters used in color densitometry?

3. What are the filters most frequently used?

837. State (1) the purpose for using prisms or diffraction gratings to modify the spectral characteristics illumination, and (2) the physical characteristic of light that brings about this modification.

Prisms and Diffraction Gratings. In color densitometers, as in spectrophotometers, a very narrow waveband is needed; so prisms or diffraction gratings are used to modify the spectral characteristics of the illumination. This modification is brought about by dispersing the light into a spectrum from which only the selected wavelength passes through a narrow slit. The wavelength of the radiation passing through the slit is determined by the position of the prism of grating in relation to the slit. The width of the waveband is controlled largely by the split aperture. Where the slit is narrow enough to pass but a single wavelength, the light is said to be monochromatic, while the device producing monochromatic light is called a monochrometer.

650

Exercises (837):

1. What is the purpose for using prisms or diffraction gratings in color densitometers?

2. What physical characteristic of light brings about this modification?

838. Define a wedge and state the purpose for using one.

Wedges. Found mostly in visual-type densitometers, wedges reduce the intensity or change the color of the measuring light. Wedges are light absorbers whose density gradient is continuously variable, usually linearly, with respect to distance along the wedge. A convenient arrangement consists of an arc-shaped wedge on a circular glass which is rotated in the measuring beam.

Exercises (838):

1. What is the purpose for using wedges?

2. Define a wedge.

839. Name the sensing device used in visual densitometers and state the disadvantage of using visual instruments for extended periods of time.

Sensors. In visual densitometers, the sensing device is your eye. Obviously, when visual instruments are used for color densitometry, you must have acceptable color vision. Also, since fatigue tends to affect the accuracy of photometric and colorimetric matches, you should not use visual instruments for extended periods of time to make a large number of readings.

Receptors for photoelectric densitometers are vacuum-type photocells or photomultiplier tubes. Since color densitometry involves the visual portion of the spectrum, only those photocells or photomultipliers whose response lies close to that region are used. Any sensitivity of the cell to wavelengths outside of the visual region is undesirable and can be eliminated by using the proper filters.

Exercises (839):

1. What is the sensing device used in visual densitometers?

2. What is the disadvantage of using visual instruments for an extended period of time?

840. Explain how information about a sample is transmitted by the photoelectric color densitometer and state the disadvantage of using a photoelectric color densitometer whose output is proportional to the transmittance.

Indicators. In photoelectric color densitometers, information about the sample is transmitted to a measuring or recording device by amplified electrical signals. If output from the amplifier is proportional to the transmittance, the scale on the meter is divided into logarithmic increments to yield density measurements. This meter has one disadvantage. The compressed graduations at the high-density end of the scale are often misread by inexperienced or tired operators, so inaccurate readings are obtained. A better instrument to use is one with an electronic network whose output is directly proportional to density measured. This kind of meter has a scale divided into regular increments, which is marked directly in terms of density.

Some instruments operate on the null principle and have an indicator that simply indicates that the impulses from two light beams are in balance. With instruments of this type, densities are read from scales attached to the attenuator used to establish a balance between the two beams.

Exercises (840):

1. Explain how information about a sample is transmitted by the photoelectric color densitometer.

2. What is the disadvantage of using a photoelectric color densitometer whose output is proportional to the transmittance?

841. Name two instruments that can be equipped to record spectral transmittance and density values.

Recorders. Any electronic color densitometer or spectrophotometer can be equipped with a recording device. Spectrophotometers are usually capable of recording both spectral transmittances and density values as functions of wavelength; whereas densitometers generally trace density curves on a linear chart recorder. Some densitometers are equipped to provide direct signal readout which can be channeled to typewriters, punched cards, or tape. Such systems are useful where large quantities of data must be processed.

Exercises (841):

1. List the two instruments that can be equipped with a recording device.

2. Where large quantities of data must be processed, what instrument is recommended?

842. State how you would measure diffuse transmission density.

Geometric Considerations. At present, the only standardized geometrical arrangement of color densitometers is that which measures diffuse transmission density (according to the ANSI Standard PH 2.19–1959). Any type of densitometer may be calibrated to give diffuse density values for any one type of photographic material. However, if accurate evaluations of other photographic materials are required, new corrections must be determined and the instrument should be recalibrated.

Exercises (842):

1. What does the standardized geometrical arrangement of color densitometers measure?

2. If you seek accurate evaluations of other photographic materials, what should be done to the instrument?

843. Explain the difference between a direct-reading and null-reading integral densitometer.

Integral Densitometers. Integral color densitometers may be either direct-reading or null-type instruments. Individual differences between the two kinds of instruments are illustrated in figure 4-7. A direct-reading densitometer is usually calibrated by measuring the output radiation with no sample in place. Under these conditions, the density reading is adjusted to zero, and all density readings following are made against that reference. The chopper in figure 4-7,A is not always included in direct-reading densitometers; but when it is included, an alternating signal is produced by interrupting the measuring beam. The signal is amplified and rectified to produce a DC signal that is proportional to transmittance. By applying this signal to a logarithmic meter, a deflection of the needle that is proportional to density is obtained.

The sole function of the receptor in a null instrument is to establish the equality of response to the energy contained in two separate light beams and to indicate when a mismatch occurs. The light in a null instrument is divided by a beam splitter, as shown in figure 4-7,B. Note that one half of the light passes through the sample, and the second half takes another path to reach the receptor. The attenuator may be in the same beam with the sample, as seen in the figure, or it may be placed in the other beam. In the first instance, combined densities of the wedge and the sample are made to match the comparison beam. In the second case, the comparison beam is attenuated to match the sample. In either case, densities are read from a scale connected to the attenuator.

Exercises (843):

1. Refer to figure 4-7. What are the individual differences between the two kinds of instruments?

844. Explain how black-and-white densitometers can be used for color densitometry.

Three-Filter Densitometers. Instruments that are suitable for black-and-white density measurements are also suitable for color densitometry—if they are equipped with red, green, and blue filters for integral color-density measurement. While the results obtained from these instruments have only limited significance, the three-filter densitometer is widely used in imagery production laboratories.

Exercises (844):

1. Can black-and-white densitometers be used for color densitometry? Explain.

845. State the principle of operation on which the analytical color densitometer is based; and by reference to the schematic, explain how light passes through an analytical densitometer.

Analytical Densitometers. The operation of the analytical color densitometer is based on the principle that the absorption of the dyes in the film sample can be matched by the absorption of some combination of the three wedges, each of which contains varying known amounts of the dyes that comprise the sample. Figure 4-8 illustrates this principle. In the figure, the beam of light on the left passes through the sample, whereas the beam on the right must pass through the three wedges. Only when the absorption of the combined wedges equals that of the sample will the two sides of the split-field match. By determining the amount of absorption of each wedge, you can make a quantitative analysis of the color content of the sample. This type of instrument is also used to determine equivalent neutral densities.

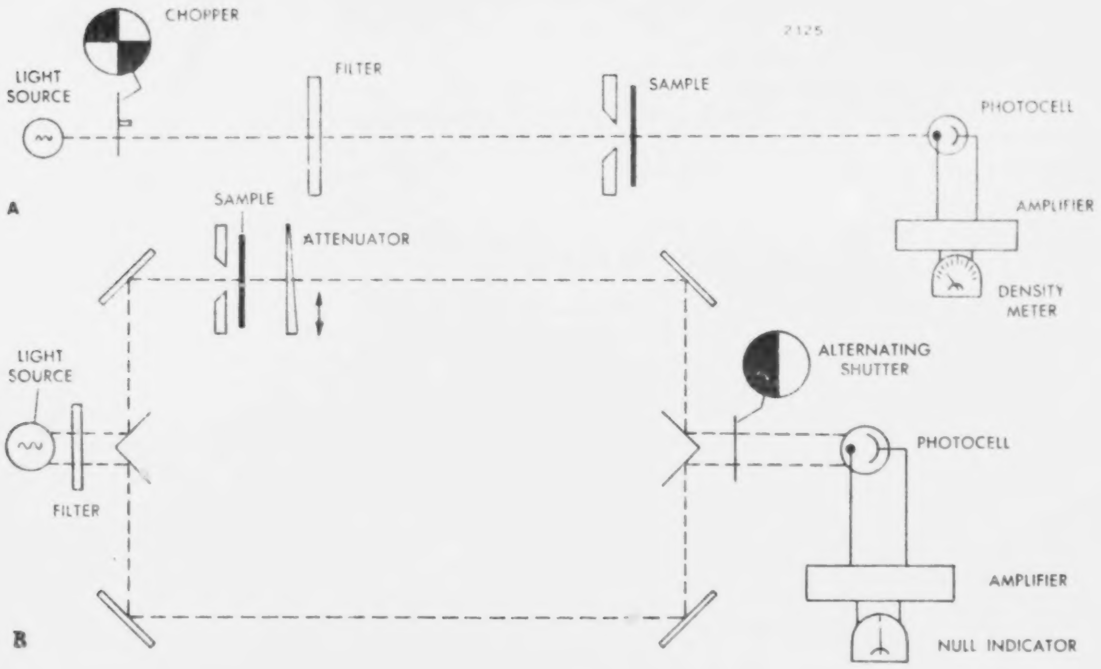

CHOPPER
2125
LIGHT SOURCE
FILTER
SAMPLE
PHOTOCELL
A
AMPLIFIER
DENSITY METER
SAMPLE
ATTENUATOR
LIGHT SOURCE
ALTERNATING SHUTTER
PHOTOCELL
FILTER
AMPLIFIER
B
NULL INDICATOR

Figure 4-7. Schematics of direct reading and null-type integral densitometers.

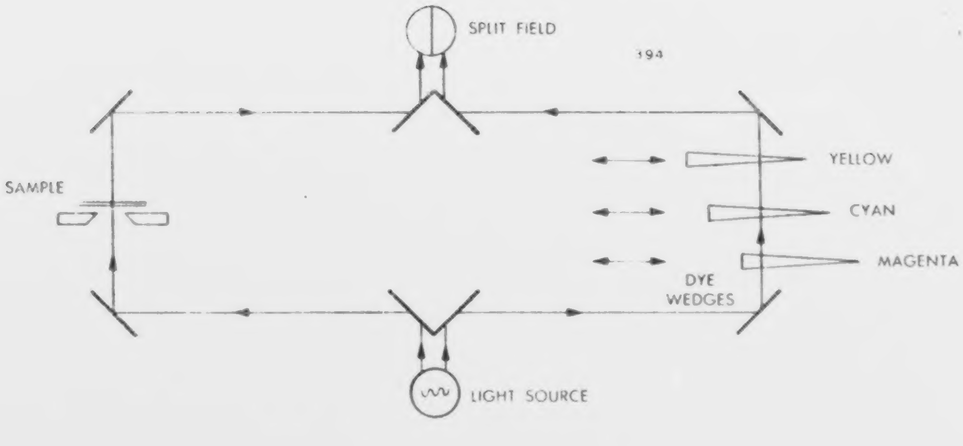

SPLIT FIELD
394
YELLOW
SAMPLE
CYAN
MAGENTA
DYE WEDGES
LIGHT SOURCE

Figure 4-8. Schematic of an analytical densitometer.

Exercises (845):

1. On what principle is the operation of the analytical color densitometer based?

2. Refer to figure 4-8. Where does the light pass through on the left and right of the figure?

4-4. Equivalent Neutral Densities

An important criterion of a color material is its ability to produce a scale of neutral densities. If you expose a color material through a step wedge or to a gray scale under proper lighting conditions and then process it correctly, a scale of neutrals or near neutrals will result. If neutrals are produced, we can assume that the component colors (cyan, yellow, and magenta) are present in the correct amounts. If something other than a neutral is formed, the component colors are not present in equal amounts, and the appearance of the patch will indicate direction of the color shift. Used in this sense, "equal amounts of dye do not indicate a physical quantity of dye, but the amounts needed to produce a visual neutral tone."

846. Explain the importance of producing a scale of neutral densities when you are evaluating color processes, and use given data to compute the ENDs of the film sample.

Neutral Densities. To clarify what is meant by the term "neutral density," let us select a uniform silver image of known density, say 0.50, and compare it with the density produced by superimposing three patches: one of cyan, one of yellow, and one of magenta. If the neutral formed by the three patches exactly matches the gray patch, we can assume that the dyes in each of the color patches are present in equal amounts and that each has a value of 0.50. We can say, therefore, that when these three patches are superimposed and viewed under specified conditions, a neutral density equivalent to 0.50 will be formed.

This concept was originally known as the gray equivalent color density and was developed with the aid of the densitometer illustrated in figure 4-9. Measurement of densities present in color film images made with this instrument are now called equivalent neutral densities, or ENDs.

To see how these principles apply, let us refer to the diagram in figure 4-9. The first step in the preparation of the instrument is to calibrate the neutral wedge. This can be done by comparing its varying densities with a series of neutral patches of known densities. The scale values of the wedge will increase linearly as the density increases. With the calibrated neutral wedge in place, the three dye wedges can be calibrated as follows: With no sample in the beam, one dye wedge is inserted in the beam at some point near its minimum density. Then, the two remaining dye wedges are inserted and adjusted until they, in combination with the first wedge, produce a neutral density. Finally, the neutral wedge is moved in its beam until its density matches the combined densities of the dye wedges, and the scale value of the neutral wedge is marked on each of the dye wedges. This process is repeated at increasing densities until the dye wedges are completely calibrated.

To make direct END measurements, you would proceed as follows:

(1) With no sample in the beam, adjust the instrument until a photometric balance between the two beams is made.

(2) Insert the sample to be tested.

(3) Adjust the dye wedges until you determine the just-required amount of the dye needed to form a neutral density with the sample.

(4) Adjust the position of the neutral wedge until the densities in the split-field match.

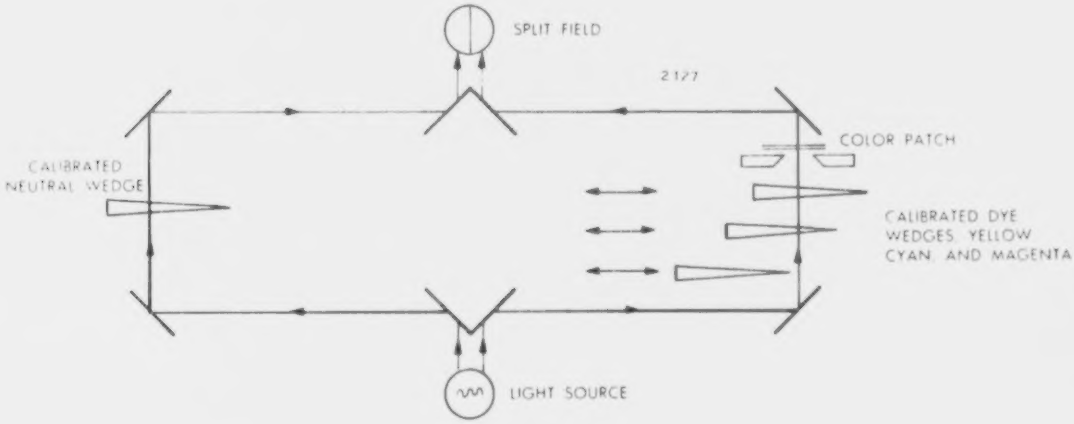


Figure 4-9. Null-type instrument for measuring ends.

(5) Read the density value from the neutral wedge and assign this value to the combined densities of dye wedges and sample.

Once the density of the combination has been determined, the ENDs of the sample may be found by subtracting the dye wedge values which were added to form the neutral. For example: Suppose that the visual density of the neutral wedge was 0.90, the cyan added was 0.00, the magenta added was 0.30, and the yellow added was 0.40. The ENDs of the three dye components of the sample are found by subtracting values, as shown in the following:

	Cyan	*Magenta*	*Yellow*
Visual density of the neutral wedge	0.90	0.90	0.90
minus END of dye wedge	−0.00	−0.30	−0.40
equals END of the sample	0.90	0.60	0.50

The ENDs shown in this sample are stated as c = 0.90, m = 0.60, y = 0.50.

The absorption curves of the dyes used in the dye wedges are critical to the equivalent neutral density readings. The dyes in the wedges should be the same as those in the photographic image. Moreover, for densitometers of this type, the log D law must hold, since the ENDs of each of the dyes must be additive.

A series of sensitometric strips exposed through a step wedge onto color material should produce a range of neutrals. Finding the ENDs of each neutral will show whether or not the patch is actually neutral, and if it is not, the direction of the color shift is shown. Figure 4-10 shows a typical set of characteristic curves of a direct-reversal color film, showing the gray-scale densities plotted in units of equivalent neutral density. The equivalent neutral densities show the visual densities of grays. This unit has an advantage in work requiring the computation of brightness ratios in the images as functions of brightness ratios in the original scene, that is, in "tone reproduction" problems.

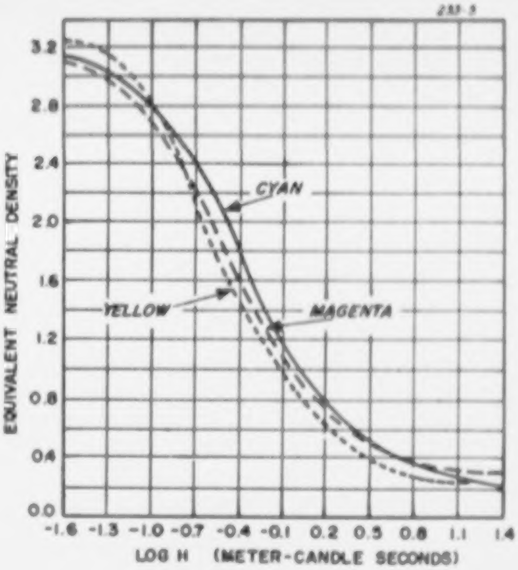


Figure 4–10. Equivalent neutral densities vs. logarithm of exposure for a reversal color film.

Exercises (846):

1. Why is it important to produce a scale of neutral densities when you are evaluating color processes?

2. Situation: You find that the visual density of the neutral wedge is 0.87 with the added magenta measured at 0.05, added cyan at 0.25, and added yellow at 0.45. Given this information, what are the ENDs of the film sample?

Construction and Analysis of Sensitometric Curves for Color Processes

SENSITOMETRY IS valid only to the degree that it aids the user. This may be the color correction of a print, interpreting manufacturer's specifications, process quality control, or a complete material evaluation. The steps involved in the sensitometric cycle closely parallel the steps in the actual production process. The sensitometric cycle differs in that it produces standardized quantitative information which can be measured, compared, displayed, and communicated. This is untrue of pictorial images, which are the subjective product of the process.

To be effective, the sensitometric data obtained from a processed control strip must be displayed and interpreted. Several different display methods are presently used for various color processing applications. Two, in particular, are the characteristic, or sensitometric curve, and the control chart, both of which have their advantages and disadvantages. The choice of plotting techniques depends solely on the specific application and information desired. Sensitometric curves are normally constructed to evaluate material characteristics and to establish standards for both the material and the process. Once these standards have been established for the process, the control chart becomes the common method of monitoring these controls. No matter which method is used, they should show the variance in such things as speed, color balance, stain level, and maximum density.

5-1. Construction of the Characteristic Curve

The primary method of displaying densitometric data is by the use of the sensitometric curve, since this form provides a wider range of information. This chapter will cover the construction and analysis of the characteristic curve as applied to color negative and positive materials. It is necessary that the technician thoroughly understand the process in order to interpret and apply this information.

847. Identify those factors necessary for the construction and analysis of the characteristic curve as it applies to color negative and reversal materials.

Construction of the Characteristic Curve. In the construction of characteristic curves, the horizontal (abscissa) axis of the graph will be computed in the same manner for both negative and positive color materials. The characteristic curve (sometimes referred to as the H & D or D log H curve) relates color density to the logarithm of exposure and can be used to show either absolute or relative information. When exact information about the exposure is required (such as film speed calculations), the absolute curve is required. Normally, only the relative curve is plotted, since it requires less computation most of the desired information about the process. No matter which type of curve is plotted, the light output of the sensitometer must be known.

Exposure (H) is a product of illuminance and time (H = I × T). To determine the light output of a sensitometer, the illuminance (intensity) and time (duration) must be known or measured for the particular sensitometer being used. The intensity of the light source is normally stated in metercandles and the time or duration in seconds or fractions thereof. When both values are converted to logarithms, they are simply added and the sum becomes the log of exposure in metercandle-seconds (MCS). For example, using the EG & G Mark VI Sensitometer, the output is 1000 metercandle seconds with the 10^{-2} switch depressed. Converting this value to a logarithm yields an H of 3.00. To produce approximately equal exposures at all three time settings with this sensitometer, two attenuators are supplied, a 1.00 ND attenuator, to be used with a 10^{-2} setting, and a 1.70 for the 10^{-3} setting. Since the 10^{-2} switch was used along with the proper attenuator in the above example, the 1.00 ND factor must be subtracted from the log H of 3.00 to find the amount of actual light that is passing through the attenuator.

Most films will require additional filtration to meet their particular sensitivity or color balance. Neutral density filters are used to match the sensitivity requirements, while either color conversion or color compensating filters are used for the color balance corrections.

Suppose, for demonstration purposes only, that Kodak Ektachrome MS Aerographic Film 2448, is being evaluated, which requires an ND filter of 1.50. Also, to obtain correct color balance, an additional CC10Y filter must be used to compensate for discrepancies in this particular exposing light source. Since the ND filter is already a logarithm, we only have to determine the ND value or base density of the CC10Y filter. (This is accomplished by using the densitometer and the No. 106 or visual filter in place and reading its density.) In this case, the CC10Y filter has a base density of 0.04. Simply by adding these ND values together, we can obtain the total lightstopping ability of these two filters, which is 1.54. To find the amount of light that is reaching the original stepwedge, we subtract the 1.54 ND factor from the output of 2.00, which would be 0.46, or an antilog of 2.88, which is the MCS of the original exposing light source.

At this point, it must be determined whether an absolute H or a relative log H graph is to be constructed. If the absolute log H graph is desired, each of the density values from the original stepwedge must be determined and subtracted for the log H of 0.46. The lower horizontal axis of figure 5-1 is an example of an absolute log H graph and is based on an 11 stepwedge. Each step along this axis represents the exact exposure the film received in order to produce the corresponding density above. Since the absolute log H graph is so time consuming to construct, it is normally used only when exact exposure computations are required.

The relative log H is most commonly used, since it is the faster and simpler of the two methods to construct. Most of the information desired about the process and color balance can be obtained from the relative curve, as well as the relative exposure values.

In the construction of the relative axis, all that is required is the log of exposure at the original stepwedge (which, in our example, is 0.46), and the density of the maximum step of the original stepwedge (step No. 11 and 21, depending on the wedge that is being used). The maximum density step is subtracted from the log H, and the difference becomes the absolute exposure required to produce the density above the 0.00 step on the relative axis. For an example, we will use a 2.97 for the maximum density of the original stepwedge. This density is subtracted from the log H of 0.46 and the difference ($\bar{3}.49$) would represent the exact amount of light that is striking the film at this particular step. The figure $\bar{3}.49$ would be placed beneath the zero point on the graph, which becomes the starting point for the construction of the relative axis (fig. 5-1). The zero point is placed on the left side of the axis and the remaining steps are marked off to the right. Since the 21-step wedge has an approximate 0.15 density change between its steps, the remaining 20 steps are marked off to the right in increments of 0.15 (or 0.30 density increments, if the 11 stepwedge is used) from point 0.00. This completes the relative axis and all that remains is the constructing of the density (vertical or ordinate) axis and plotting the densities of the test.

Once the graph has been completed, exposure may normally be computed from any place along the characteristic curve to within an accuracy of ± 0.04 or 1/8 of an f/stop of the exact exposure. This accuracy will depend largely on how true the density differences are on the original stepwedge.) For instance, to determine the exposure that produced the midstep of a curve, you would use the following procedures. Locate the point of interest on the curve, drop straight down to the relative axis and obtain that density value, add this value to the absolute log H value point 0.00. The value would be the approximate exposure required to produce that density point on the sensitometric curve.

When it is necessary to plot a set of color curves from a control strip with no exposure data available (such as manufacturer's preexposed control strips), they may be constructed using the density versus density or modified relative log H method. The modified method is constructed identical to the relative log H scale, except there is no absolute log H value placed at 0.0 point.

The construction of the density axis is also identical to that of black and white evaluations. The zero density value is placed on the base line of the graph, and the remaining density values normally increase from this point in 0.20 increments upward to include the maximum density level of the material that is being evaluated. However, one exception is that the density axis of color materials is labeled with the type of filters used in the densitometer to perform these density measurements.

Once the horizontal and vertical scales are constructed and labeled properly, the next step is to plot the densities from the produced stepwedge. Unlike the black and white emulsion which yields one characteristic curve, color films have three such curves, each representing the exposure versus (dye) density relationship for approximately one-third of the visible spectrum.

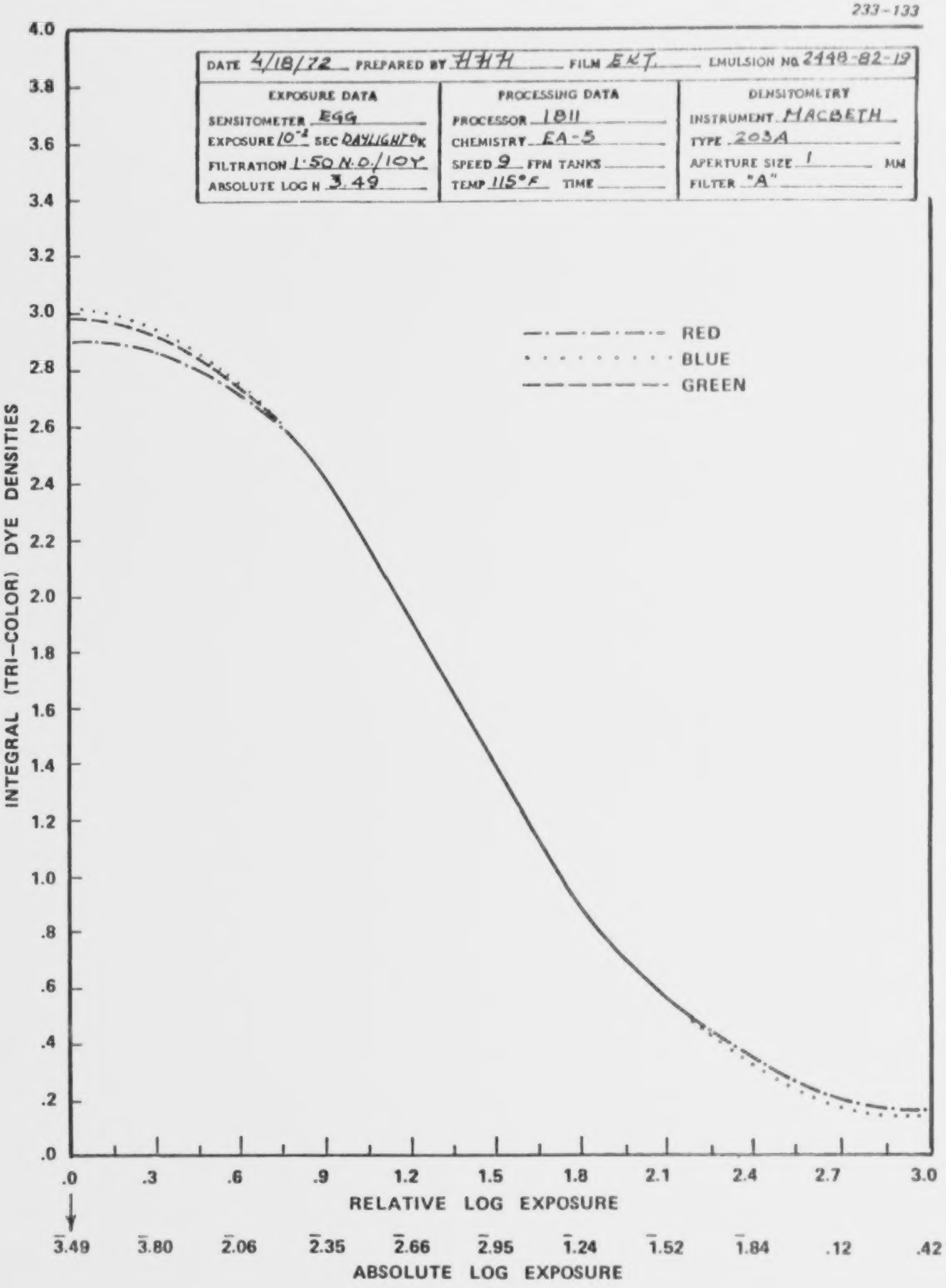
Since the density readings obtained are of the arbitrary three-filter integral type, each curve is plotted in the same color as the filter used in the densitometer to obtain the data. Hence, upon completion, the family of curves will be the three primary colors: red, green, and blue. For example, the blue density curve will represent the total effect of opacity of the yellow dye absorption within the emulsion as a whole. If the exact dye concentration of each individual layer of the emulsion is required, analytical densities must be determined. To graphically illustrate analytical densities, the secondary colors are used (yellow, magenta, and cyan). However, analytical density determinations are beyond the scope of this course.

Since color films generally are designed so that a scale of neutral exposures will result in a scale of dye neutrals in the final image or product, the three color curves will be superimposed under ideal conditions and can be considered as a single curve. However, due to the type of density measurements and other factors within the system, it is possible to produce a neutral stepwedge without superimposing the color curves on the graph. Normally, for proper determination, the stepwedge's neutrality is evaluated under the light source to which the final product is to be displayed.

Exercises (847):

1. The sensitometric cycle is designed to produce what kind of information?

2. What are the two display methods used to obtain densitometric data?



DATE 4/18/72 PREPARED BY HHH FILM EKT. EMULSION NO. 2448-82-19

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER EGG	PROCESSOR 1811	INSTRUMENT MACBETH
EXPOSURE 10^{-2} SEC DAYLIGHT °K	CHEMISTRY EA-5	TYPE 203A
FILTRATION 1.50 N.D./10Y	SPEED 9 FPM TANKS	APERTURE SIZE 1 MM
ABSOLUTE LOG H 3.49	TEMP 115°F TIME	FILTER "A"

Figure 5–1. A family of curves utilizing a relative log H axis and an absolute log H axis.

3. Where standards have been established for the process, what method is used to monitor the controls?

4. This objective is concerned with what method for displaying densitometric data?

5. What kind of curve is constructed when exact information about exposure is required?

6. Exposure is a product of __________ and __________.

7. How is the intensity of the light source stated?

8. The product of intensity and time converted to logarithms becomes what?

9. How much light is held back with a ND filter of 0.30?

10. In constructing a relative axis, what is required?

11. Color films have three curves representing approximately what fraction of the visible spectrum?

12. The blue density curve represents the total effect or opacity of what dye absorption within the emulsion as a whole?

13. In question 12, are we reading integral or analytical densities? Explain.

14. When plotting the three color curves, an ideal neutral exists when all three curves are represented by what?

848. Interpret the characteristic curve, and state the effect of exposure on dye density on reversal materials.

Interpretation of the Characteristic Curve. In discussing the interpretation of the characteristic curve for both color negative and positive materials, it will be assumed, for simplicity, that the "ideal neutral" exists and *that all three* dye layers can be represented by a single curve. (This situation never occurs in reality.) Figure 5-2 shows a curve representative of an unmasked negative color film, which can be divided into three distinct parts. As the exposure increases from A to B along the horizontal axis, the density increases from a minimum at an accelerating rate. This area is called the toe of the curve and represents the shadow area of the original scene. As the exposure continues to increase from B to C, changes in density are proportional to changes in exposure, resulting in a "straight line" or midtones. As exposure increases from C to D, the rate of density change decreases progressively, resulting in a rounding off of the curve, until maximum density is reached. This portion is known as the shoulder and denotes the highlight areas.

These same three areas are apparent in figure 5-3, which represents the response of reversal color films. It should be noted that, because of the reversal image characteristics of the material and its process, an increase in exposure produces a decrease in density. The three areas of the curve retain their designation. For example, the high-density area, from A to B on the log H axis, still remains the shoulder. However, in reversal materials, the shoulder represents the shadow areas of the original scene. In this portion of the curve, density decreases at an accelerating rate. Increasing exposure from B to C again produces a proportional decrease in density, resulting in a "straight-line," while a continuing increase in exposure from C to D results in a declining rate of density change in the "toe" area as minimum density is approached. This area is known as the highlights, which represents the maximum reflectance or exposure from the original scene.

Exercises (848):

1. Because of reversal image characteristics, an increase in exposure produces what kind of a dye density?

2. In reversal material, the shoulder represents what part of the original scene?

3. In reversal film, the area known as the highlights represents what characteristic of the original scene?

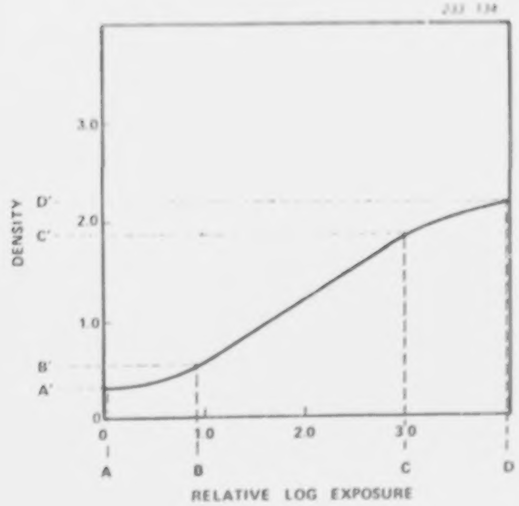


Figure 5-2. Characteristic curve representing an unmasked color negative film.

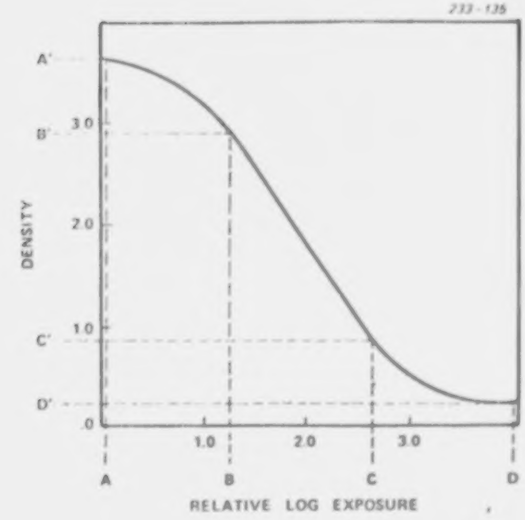


Figure 5-3. Characteristic curve representing a color reversal film.

849. State the factors that influence the shape of the characteristic curve.

Factors Influencing the Shape of the Curve. The exact shape of the characteristic curve depends not only on the particular photographic material but also on many other factors, among which are the spectral quality and intensity of the exposing light, the exposure time, the physical conditions under which the film is stored, exposed, and processed, the chemical composition of the processing solutions, and the instruments used for measuring the densities. It will not be possible to discuss all these factors. Instead, attention will be directed to those basic items which are most pertinent to the evaluation of color materials from the exposure and processing aspects. The following discussion will be concerned with the effect of exposure on the density produced, procedures for determining the base plus fog, contrast, and latitude as applied to both negative and reversal films.

Exercises (849):

1. What are several of the factors that influence the shape of the characteristic curve?

850. Interpret data from the characteristic curve in terms of the shape of the curve, and the curve's position relative to the log H axis.

The Effect of Exposure on the Curve. In discussing the effect that exposure has on the density which produces the characteristic curve, two areas must be mentioned: (1) the positioning of the curve as compared to the log H axis and (2) the shape of the curve itself.

If two different emulsions are being evaluated for their exposure characteristics, a sensitometric strip must be exposed and processed under uniform conditions for each emulsion. After computing the log H values for each sensitometric strip, it is found that the values are different and, when plotted, they will occupy different locations along the log H axis. It will be noted from the relative log H axis in figure 5-4 that exposure increases from left to right along this scale. Since the least exposure occurs through the denser steps of the original stepwedge, it is evident that the exposure scale intervals for the denser steps be positioned to the left side of the horizontal scale. Hence, after construction of the curves, negative #1, which lies farthest to the left, required the least exposure and would yield the highest sensitivity.

Thus, if the log H separation for the two curves was 0.30, as shown in the illustration, negative #1, which is farthest to the left, would yield a speed twice that of negative #2. A rule to remember is that anytime a value is placed on the log H axis, any subsequent value having an increase in exposure will be moved or placed to the right of that point along the axis. A decrease in exposure will be decreasing logarithm and will be shifted to the left from the original value. This rule holds true in the construction and analysis of the log H axis for all materials, whether it is black and white, color, negative, or reversal.

However, when only the shape of the characteristic curve is being considered, while disregarding the log H axis, the effects of exposure are somewhat different for negative and reversal films. In the evaluation of negative curves, the toe area is flat at its extreme end, representing the base-plus-fog density of the emulsion. The length of this flat portion of the toe is affected by the amount of overall exposure the film has received. If the exposure is low, the flat portion of the toe will be longer and the straight-line portion will be moved down and to the right. (See fig. 5-5,A.) On the other hand, increasing the exposure will shorten the flat portion of the toe and move the straight-line portion to the left. (See fig. 5-5,C.) Figure 5-5,B represents correct exposure and a normal shaped characteristic curve.

In reversal films, the opposite effects occur, since the D_{max} of the final product is achieved in the areas of no exposure. As exposure increases, the density decreases in reversal materials. Note in figure 5-6,A, if the exposure is low, the flat portion of the toe will be shorter and the straight-line will move up and to the right as compared to the correctly exposed curve shown in figure 5-6,B. An increase in exposure will lengthen the toe, and the straight-line will be down and to the left of the normal curve. This is shown in figure 5-6,C.

In determining the proper exposure for sensitometric evaluations of both negative and reversal material, a suggested procedure would be as follows. Adjust the exposure of the sensitometer until two steps within the toe are identical in base density readings. Steps 20 and 21 of the produced sensitometric strip are used for negative material and steps 1 and 2 for reversal when using a 21 stepwedge. Two steps are used simply to verify that base density has been obtained. This makes available the remaining 19 steps of the wedge to yield information on the effects which exposure and processing solutions have on the particular emulsion that is being evaluated.

Exercises (850):

1. If the log H separation for two curves is 0.30, then the curve farthest to the left would be how much faster than the other emulsion?

2. In reversal color films, the D_{max} of the final product is achieved in what area of exposure?

3. As a rule, the exposure within the toe should have how many steps for base density readings?

851. Define exposure latitude, and identify those factors that affect it.

Exposure Latitude. Latitude expresses the ability of a photographic emulsion to record, in a single exposure, satisfactory detail in both the light and dark areas of the original scene. In the past, exposure latitude has been determined by the projection of the straight-line portion of

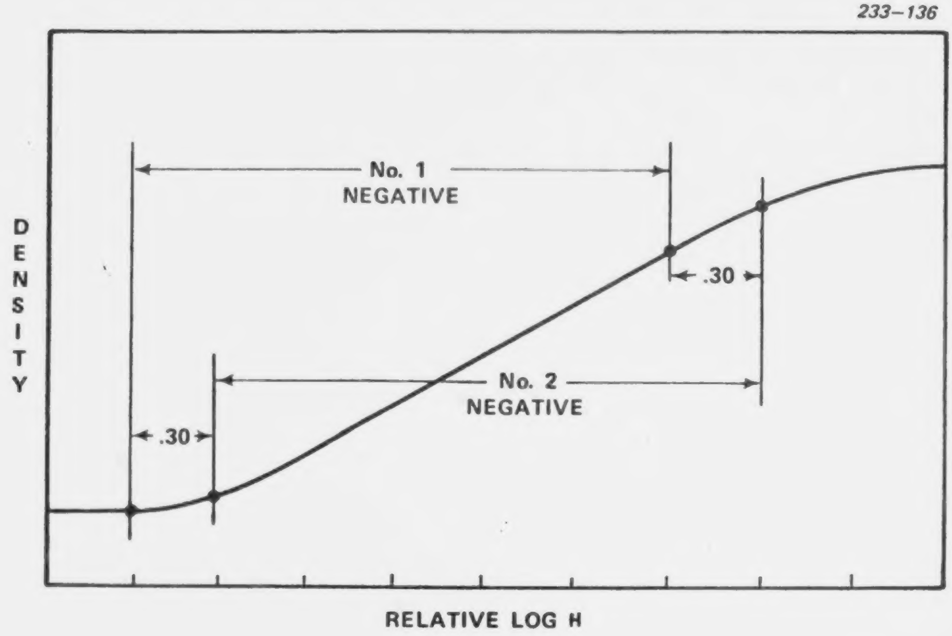


Figure 5–4. Comparison of negative film sensitivity.

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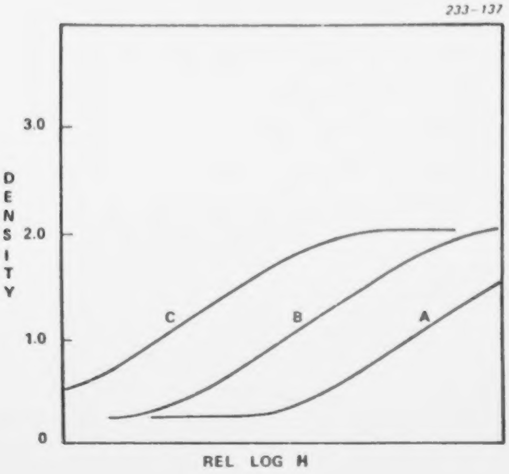

Figure 5–5. Effects of exposure of color negative films.

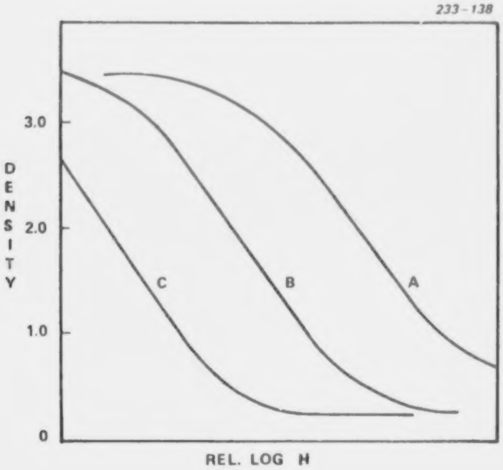

Figure 5–6. Effects of exposure on color reversal films.

the characteristic curve on the log H axis. This straight-line area represents the latitude of a particular film processed to specified conditions, which is noted by the change in density proportional to the changes in exposures.

Obviously, as the slope of the straight line becomes greater, the latitude will decrease. Therefore, latitude is directly affected by many variables, such as the process, the scene brightness range, etc. It follows, too, that high contrast films (such as color reversal) will, in general, have a shorter latitude than that of lower contrast color negative materials.

In establishing a speed criterion for modern emulsions, especially in the case of camera (or original) films, it has been found that exposures are seldom confined entirely to the straight-line region of the curve. For this reason, most updated film-speed formulas affix a speed point at some point on the toe region of the characteristic curve. This allows the maximum scene brightness range to be recorded for that particular emulsion.

Exposure latitude (the phrase implying that there is a tolerance in camera exposure level) exists only if some variation in exposure can be made without sacrificing image quality. For the best possible quality, the tolerance is very small. If, on the other hand, the photographer has no alternative but to vary from the standard exposure index, then it is possible to obtain a different effective speed by varying the process. Keep in mind that this may cause some loss of image quality. Figure 5-7 shows the relationship between a color reversal and negative film. The graph illustrates the difference in their latitudes and the effects of exposure on image quality.

In this figure, the curve representing a reversal film indicates that exposing this type material is extremely critical. A 1-stop variation, either over or under the ideal exposure, can produce an unsatisfactory transparency. Also note that image quality decreases rapidly with reversal material. However, color negative films offer a greater latitude. A 1-stop error in exposure can usually be compensated for during the printing step. For a scene of average brightness range, color negative film exposed from 1 to 2 stops of the proper exposure will be satisfactory for making good quality prints. Beyond 2 stops, the image quality is greatly affected.

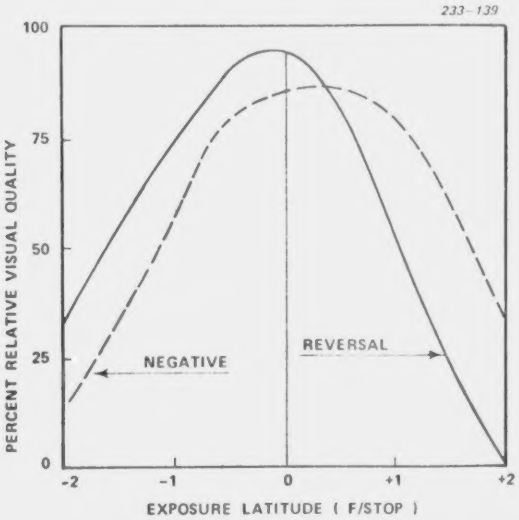

Figure 5–7. Exposure latitude comparison between color negative and reversal film.

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Exercises (851):

1. The ability of a photographic emulsion to record in a single exposure satisfactory detail in both light and dark areas of the original scene is called __________ __________.

2. Mention two of the variables that affect the exposure latitude of the film.

3. In general, color reversal film will have what kind of exposure latitude as compared to color negative film?

4. Where do most updated film speed formulas affix their speed point?

852. State the fog factors that affect the density of color films.

Base Density and Fog. In black-and-white control work, the usual practice is to record the overall densities of the control strip with little reference to base density or fog. However, with color materials, more emphasis should be placed on this evaluation, especially if the film being processed is of a questionable age or suspected of having been subjected to unusual handling conditions. The density of the support itself, or base density, can be determined simply by measuring the density of a piece of raw stock that has been bleached and fixed without receiving exposure or development. The measurement of fog is more complex, because of the different effects it will produce between negative and reversal films. Fog is also more susceptible to the color emulsion, since not only a shift in density occurs, but a color shift as well.

A small amount of fog is unavoidable in emulsions, especially when they are fully developed as in aerial photography. However, an excessive amount of fog will affect the general density of the subject, which yields a reduction in contrast. Fog can be a product of one or a combination of chemical action, thermal radiation, or other forms of radiation. The results of fog may be either an increase or decrease in density, depending upon the type of material.

For color negative material, the net fog value for a given development time is obtained by subtracting the base density from the density of the unexposed area of the toe section. Since some of the color negative films incorporate a dye mask within its emulsion, there will be a separation between the three color curves. The fog value in this case may be determined from the lowest density curve, which is normally the red sensitive emulsion or the cyan dye layer. In negative material, an increase in fog will produce an increase in overall density (more apparent in the toe area) and will yield an overall reduction in contrast.

With reversal materials, the procedures are more complex since fog will produce a decrease in density instead of an increase. In determining the fog value of reversal films, two factors must be established—the D_{max} and the base density of the particular emulsion. Base density can be determined from the toe (overexposed area of the curve). However, unlike negative materials, fog will affect the shadows or D_{max} area of the shoulder portion of the characteristic curve. When both D_{max} and base density values have been established for a particular emulsion, the fog value of the test may be determined by subtracting the maximum density of the test from the standard. (See fig. 5-8.) Note that an increase in fog will produce a decrease in density and a lower overall contrast.

All color films are constructed of three separate emulsion layers, each having a different color and speed sensitivity. The effects of fog not only produce a density change but will also a shift in color balance. The color will depend on the type of fog the material is exposed to, and may affect one or more of the color curves. There is no way to correct fogged film! Ideally, all color materials should be sensitometrically evaluated before use (especially original camera films) to provide information on their characteristics, one of which is the effect of fog.

Exercises (852):

1. Name several of the fog factors that affect the density of color films.

2. In negative color film, an increase in fog will produce what kind of density in the toe area?

3. What two factors determine the fog value of color reversal film?

853. Identify terms that indicate the proportional changes in density that are relative to changes in exposure.

Contrast, Gamma, and Average Gradient. The term contrast is frequently applied to the slope of the characteristic curve at some point, or the slope of the straight-line connecting two specified points on this curve. Contrast is widely used to indicate the proportional changes in the density as related to the changes in exposure which produced them. If, for example, a log exposure internal (Δ log H of 0.30 produces a density difference (Δ D) of less than 0.30, the contrast of the material would usually be considered low. Likewise, a Δ D above 0.30 probably would be considered a higher contrast, although the evaluation would depend on the material and its intended

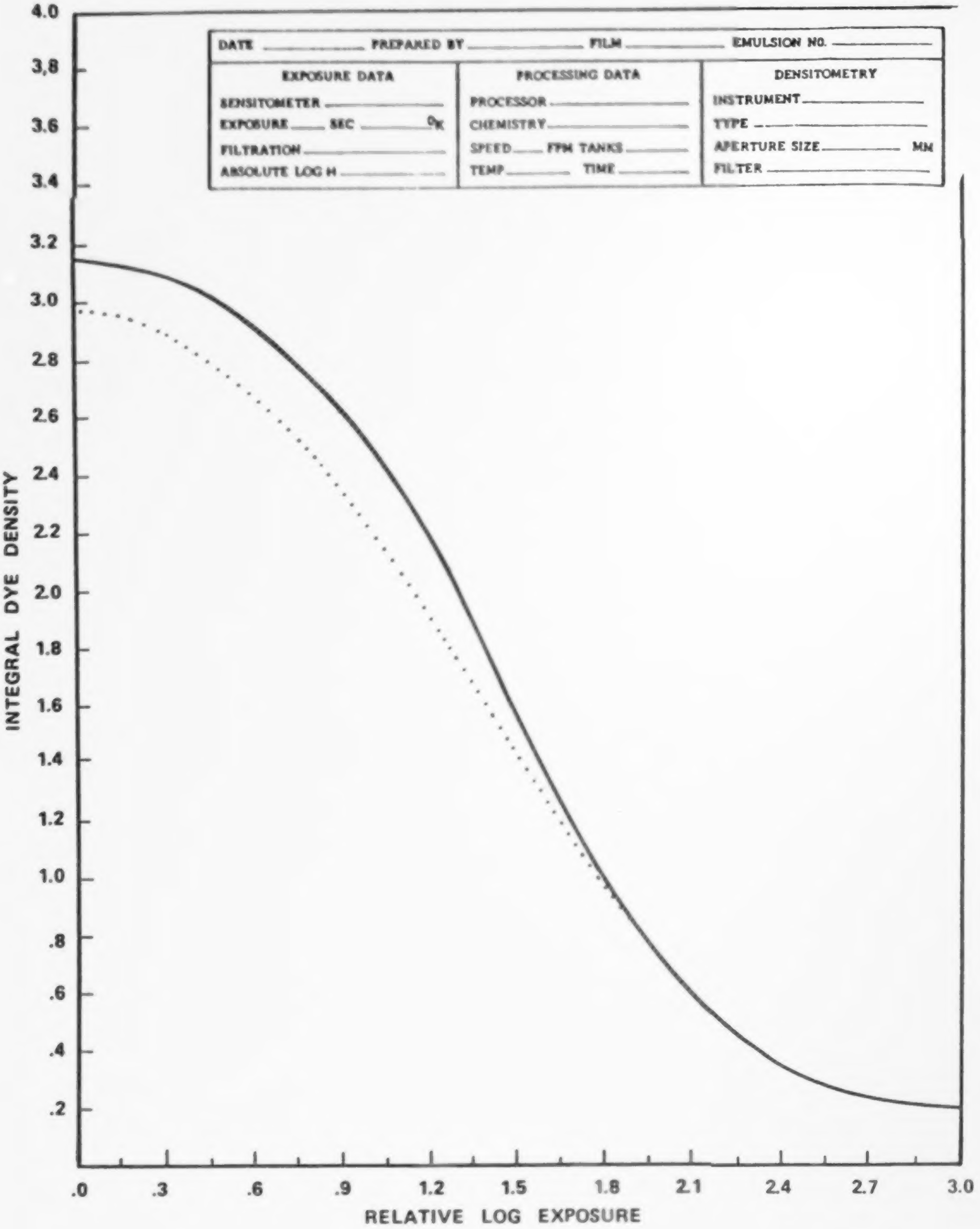

Figure 5–8. Illustration of the effects of fog on a reversal film.

use. Referring to the curves of figures 5-2 and 5-3, the Δ D values would be lower for the straight-line portion of the color negative curve (5-2) than in that of the reversal material (5-3). Thus, the reversal material would be considered to have a higher contrast than the negative material.

An objective method of designating this relationship is the term *gamma*, which is the numerical description of the effect of development contrast. Gamma is the slope of the straight-line portion of the curve. There are several procedures used to compute gamma, one of which is shown in figure 5-9. Gamma can be calculated by dividing a convenient Δ log H on the straight-line portion of the curve ($\Delta \log H = \log H_2 - \log H_1 = 1.80 - 0.80 = 1.00$ in the illustration) into the resulting Δ density ($\Delta D = D_2 - D_1 = 2.63 - 1.09 = 1.54$).

$$\text{Gamma } (\gamma) = \frac{\Delta D}{\Delta \log H} = \frac{1.54}{1.00} = 1.54$$

Gamma is a useful measurement in many black-and-white materials when it varies continuously over a wide range of development conditions. However, some black-and-white and many color films show much smaller changes in gamma with variation in development. Also the characteristic curves of some films have little or no straight-line portion. For these reasons, many laboratories have adopted an average gradient ($\bar{G}$) measurement of contrast, which is based on a specified portion of the characteristic curve. In this method, the slope of a line between two points on the curve is stated. In figure 5-9, the average gradient between points D_3 and D_4 is shown by the $\bar{G}$ line. The value of $\bar{G}$ is calculated by using the following formula.

$$\bar{G} = \frac{\Delta D}{\Delta \text{Log } H} = \frac{D_4 \quad D_3}{\text{Log } H_4 - \text{Log } H_3} =$$

$$\frac{1.80 - 0.20}{2.80 - 1.34} = \frac{1.60}{1.46} = 1.09$$

Although the average gradient has an advantage over gamma in that the two points used are more easily determined than is the straight-line portion of the curve, there is no widely accepted definition of how these points should be chosen. Each laboratory, with the cooperation of the photo-interpretation section, can establish these standards by considering the following factors: Range of average scene, type of film, exposure, the process, and how the end product is to be viewed. Using these factors and evaluating the characteristic curves, a useful D_{max} and D_{min} point can be established. One factor to remember is that these points should be far enough apart to include the range of the average scene and yet close enough to be controllable. Since reversal film yields such high densities, it is impractical to consider the entire curve. Most of the information obtained under normal viewing conditions would fall below a 2.40 density. Normally, a range from 0.15 to 1.80 can be used satisfactorily. However, any points used must be specifically identified whenever the term average gradient ($\bar{G}$) is used.

Exercises (853):

1. The term used to indicate the proportional changes in density as related to changes in exposure which produce them is called what?

2. The numerical description of the above relationship is called what?

3. Complete the following formula.

$$\frac{\Delta D}{\Delta \text{ Log } H} = ?$$

4. Films that have little or no straight-line portion of the characteristic curve use what symbol as a measure of contrast?

5. What factors are considered when determining the average gradient of a characteristic curve?

5-2. Color Balance

In the foregoing evaluations, the stepwedge is used to reproduce approximately neutral gray images; luminous densities are determined and graphically constructed. From this data, the various evaluations can be interpreted by basically the same methods which have been applied to black-and-white films. However, it must be remembered that before luminous densities are used in these evaluations, the emulsion must be in correct color balance. It has been assumed up to this point, that the stepwedge (in case of unmasked emulsions) has met the gray scale test which visually produced a neutral image. If the material does not meet the neutral gray requirements, the situation requires correction of the color balance.

854. State the characteristics of reversal material and state those factors used to achieve correct color balance.

Standard Reversal Material. In the evaluation of color curves, it may be helpful to analyze the emulsion from a practical standpoint, that of each layer sensitivity. The light sensitive coatings are arranged and sensitized so that each layer of the emulsion records a specific part of the electromagnetic spectrum, which may include either energy (light) of a single color or a portion of a broader band of radiation, such as the green portion of yellow or white light. The color recorded by a particular emulsion layer is determined by its inherent sensitivity to light, the sensitizing dyes, dye couplers, and the light-filtering action

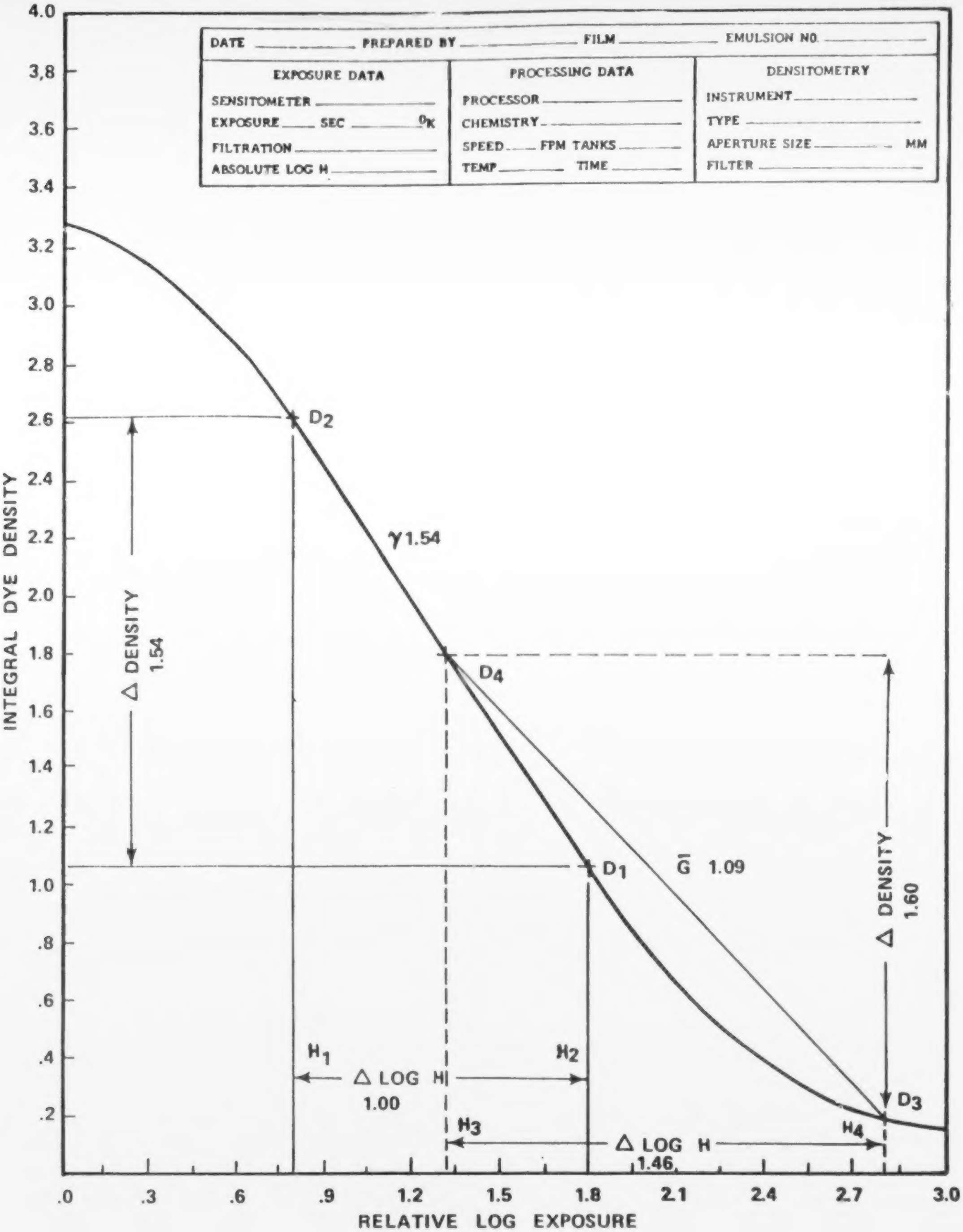

Figure 5–9. Gamma and average gradient calculations.

of other emulsions or filter layer through which the light must pass before reaching that emulsion layer. For these reasons, the speed and contrast of each layer within the tripack emulsion will vary to some degree. During manufacturing, each emulsion layer is so adjusted in speed and contrast to be used under some specific exposure conditions, illuminant, and processing, so that the photographic tone reproduction will be correct for each color recorded.

Once the family of curves is plotted, the various characteristics of the emulsion can be determined. Assuming that the tricolor density readings of the sensitometric strip agree with the visual impressions of the material being used, the tricolor curves should coincide over as much of their length as possible, particularly in the middletones (densities from 0.60 to 1.40). Since color characteristic curves are never straight and seldom coincide at all densities, they introduce complications which are commonly referred to as a color shift. A color shift can be directly related to a deficiency in exposure and color balance between the light source, the photographic material, and/or the process itself. Assuming that the process is under control at this stage, this leaves the two areas of exposure and color balance to be investigated.

In reversal films, each dye layer in the final transparency is at maximum density, without being exposed. When each of the three dye layers is at maximum density, the product will appear black. Exposure to light in a particular portion of the spectrum reduces the dye density in the layer sensitive to that color. Ideally, the overall exposure of a sensitometric strip is so adjusted that two identical density steps are produced in the toe area of the three color curves. However, due to the many factors affecting this complex emulsion, the speed and contrast within each layer can change independently. In this case, the overall exposure must be adjusted for the slowest layer, until the two steps in the toe area produce the identical base density readings. The curve that plots the farthest to the right on the graph always represents the slowest of the three emulsion layers. Once the overall exposure has been determined for this layer, the exposure of the other two layers may be reduced with CC filters until the curves coincide.

The variation of density and/or contrast within each layer of the tripack emulsion produces an out-of-balance condition or a color shift. Figures 5-10 and 5-11 illustrate two examples of color shift. In figure 5-10 the curves coincide over much of their length, but with a degree of separation between them, indicating primarily a change in density with little or no change in contrast. This condition can be easily corrected with the proper procedures. Figure 5-11 exhibits a more complicated situation, that of a change in both density and contrast of one of its curves. This effect is denoted by the crossing of the lines and normally can be attributed to either reciprocity failure or interimage effects within the given layer. All that can be done to correct this situation is to bring the curves together as close as possible over the desired density range, normally the midtones. The film can be used if the color balance is acceptable over this range, bearing in mind that the shadows and highlights will exhibit some degree of a color shift. In the event the results are unacceptable, the film with that particular emulsion number should be set aside in favor of another.

The analysis of reversal materials is simplified, since the film does not incorporate the masking dyes within its layers. To correct the color balance of this type of material, all three color curves should fall very near or on top of each other as previously mentioned. Figure 5-10 shows the sensitometric curves for a reversal color film which is out of color balance. In analyzing this set of curves, the visual appearance can be closely predicted at any given step along the horizontal axis. Example: In determining the visual appearance at step 11, a vertical line can be drawn from the horizontal axis up to intersect the three color curves. The resulting densities are shown on the density axis as Red (D_r) = 1.52, Green (D_g) = 1.30, and Blue (D_b) = 1.09. Since the dye density is what the eye sees, this step would appear quite bluish, and perhaps a little in the green direction.

Since the goal is a visually neutral wedge, color correction begins by drawing a single horizontal line at the density level where neutrality is most desirable (this point is usually established around a density of 1.00) and by dropping down to the horizontal axis (log H or relative log H) where the exposures may be determined. Record the exposures of these three points, making certain that each number is related to its proper color. Take the highest number (which represents the curve farthest to the right on the graph) as a standard and compute the difference between this number and each of the other two numbers. In the example shown in figure 5-10, these exposures are: Blue, Log H_b = 1.53; Green, Log H_g = 1.69; Red, Log H_r = 1.84. The difference between the blue and the green curves, when compared to the red curve, is 0.15 green and 0.31 blue. To shift these curves to the right to overlap the red curve, change the letter indicating the color of the curve to the letter of its complementary color. For example, red (R) becomes cyan, blue (B) becomes yellow, and green (G) becomes magenta. The two differences in the example would be recorded as 15 magenta and 30 yellow.

The rule is simple—the addition of a subtractive primary (yellow, magenta, or cyan) filter (without an overall exposure change) will cause one curve to move to the right on the relative log H axis. An additive primary filter (red, green, or blue) will cause two of the curves to be moved to the right.

If another sensitometric strip is made and processed identically to that illustrated in figure 5-10 except for the addition of the above two filters and the compensation in exposure for their base densities, the curves will appear as in figure 5-12. The three curves should coincide at D = 1.00 and with the same log H point on the horizontal axis.

Table 5-1 indicates the color-compensating filters which are available from Eastman Kodak. These filters are used in critical color work (in sensitometer and/or camera) to correct for minor variations in color balance caused by normal manufacturing variations or by causes beyond manufacturing control. The density of each color compensating filter is indicated by the numbers in the filter designation; for example, CC30Y–"CC" stands for "color compensating," "30" for a density of "0.30," and "Y"

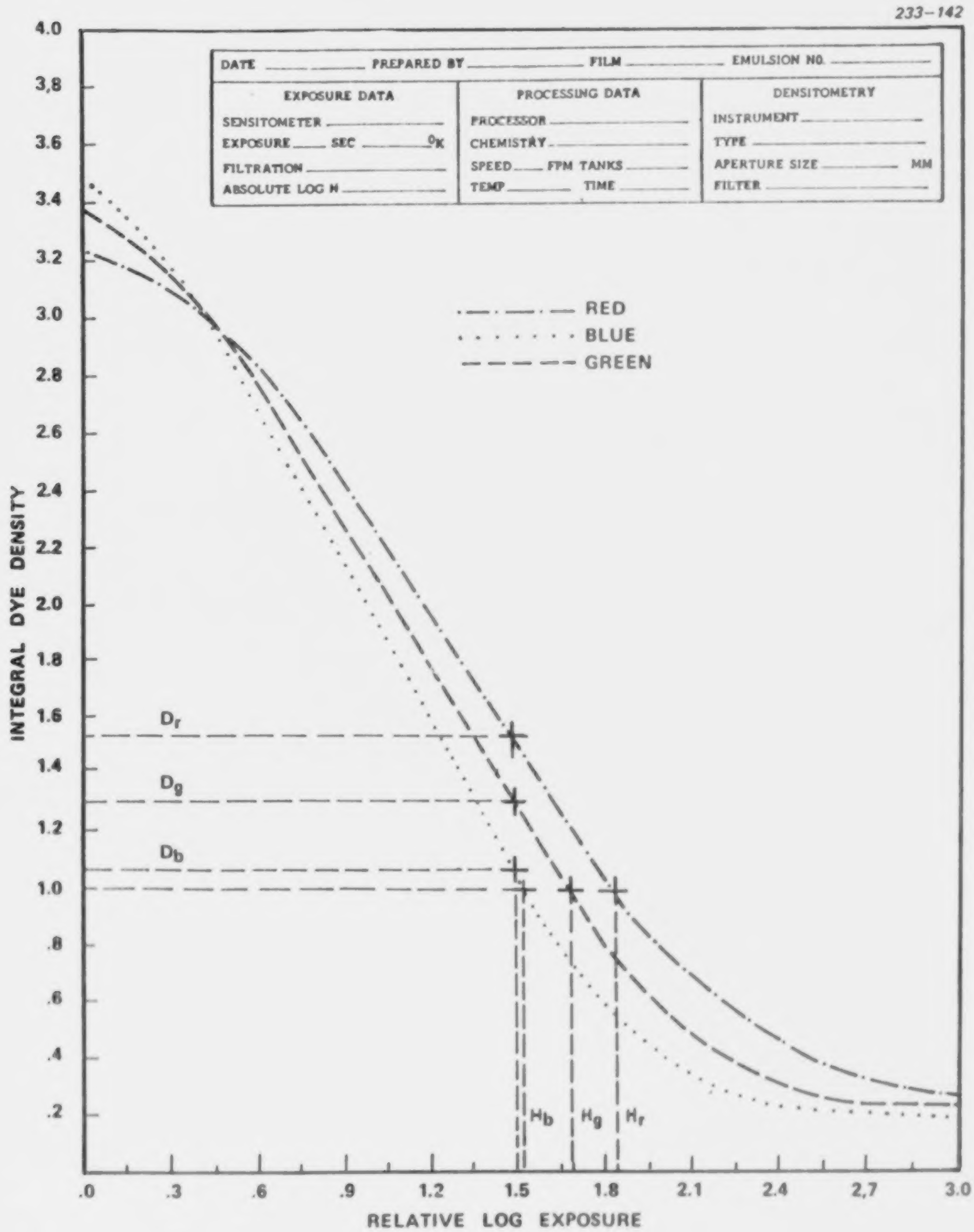

Figure 5–10. A correctable color shift in a color reversal film.

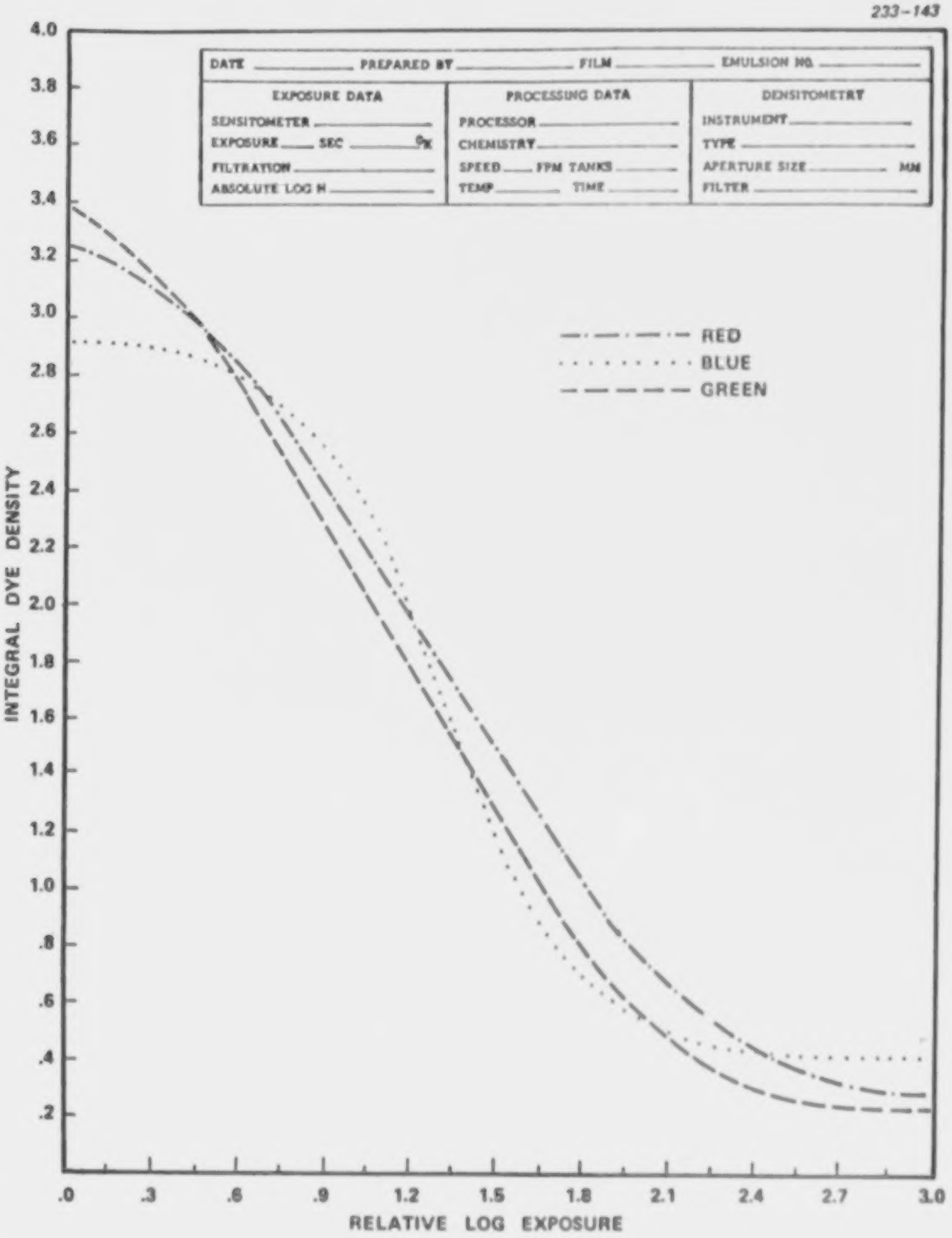

Figure 5-11. An uncorrectable color shift in a color reversal film.

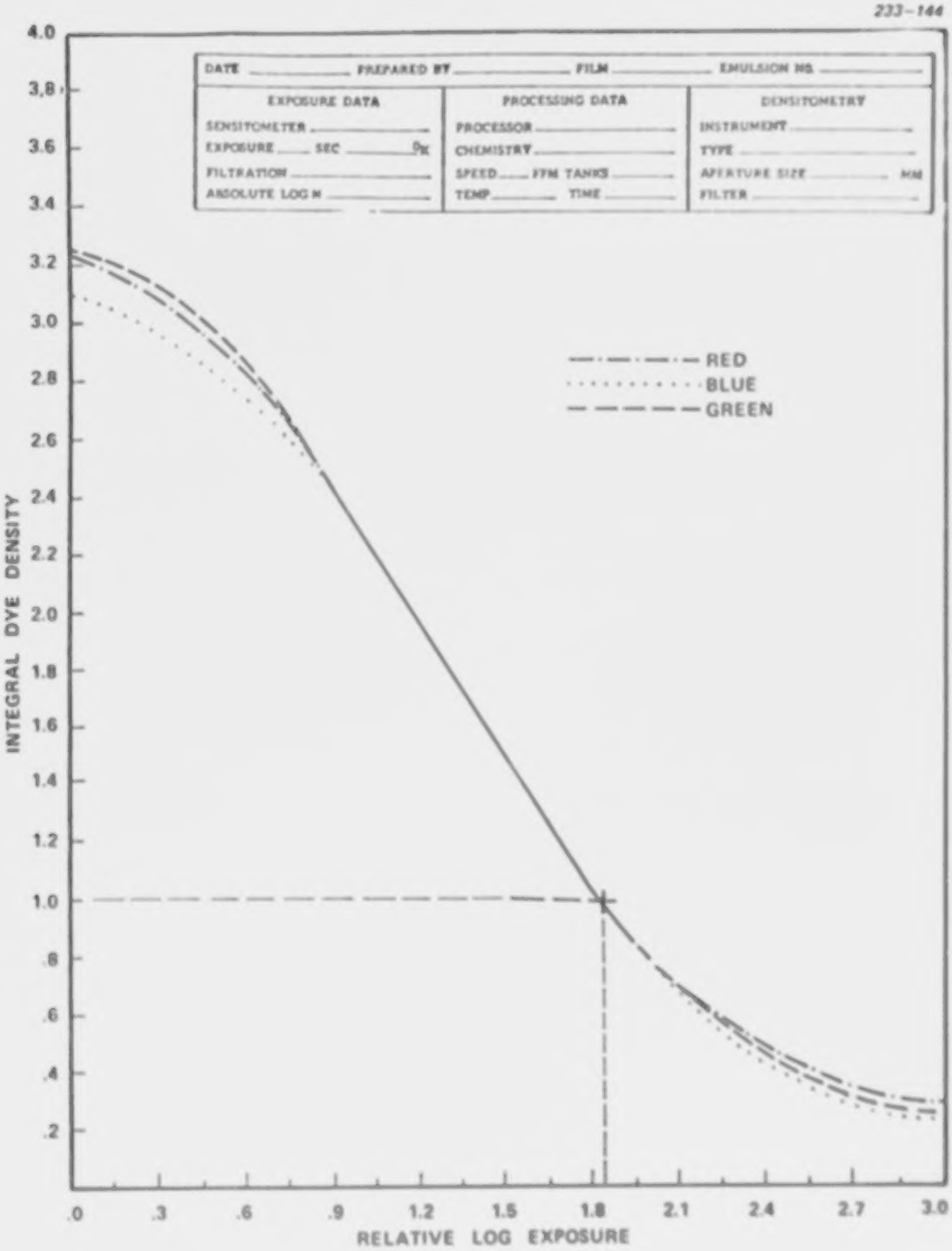

Figure 5-12. A corrected color balance in a color reversal film.

TABLE 5-1

KODAK COLOR COMPENSATING FILTERS

Peak Density	Yellow (Absorbs Blue)	Approx. Exposure Increase	Magenta (Absorbs Green)	Approx. Exposure Increase	Cyan (Absorbs Red)	Cyan-2 (Absorbs Red)	Approx. Exposure Increase
.025	CC 025Y		CC 025M		CC 025C	CC 025C-2	
.05	CC 05Y	—	CC 05M	1/3	CC 05C	CC 05C-2	1/3
.10	CC 10Y	1/3	CC 10M	1/3	CC 10C	CC 10C-2	1/3
.20	CC 20Y	1/3	CC 20M	1/3	CC 20C	CC 20C-2	1/3
.30	CC 30Y	1/3	CC 30M	2/3	CC 30C	CC 30C-2	2/3
.40	CC 40Y	1/3	CC 40M	2/3	CC 40C	CC 40C-2	2/3
.50	CC 50Y	2/3	CC 50M	2/3	CC 50C	CC 50C-2	1

Peak Density	Red (Absorbs Blue and Green)	Approx. Exposure Increase	Green (Absorbs Blue and Red)	Approx. Exposure Increase	Blue (Absorbs Red and Green)	Approx. Exposure Increase
.025	CC 025R					
.05	CC 05R	1/3	CC 05G	1/3	CC 05B	1/3
.10	CC 10R	1/3	CC 10G	1/3	CC 10B	1/3
.20	CC 20R	1/3	CC 20G	1/3	CC 20B	2/3
.30	CC 30R	2/3	CC 30G	2/3	CC 30B	2/3
.40	CC 40R	2/3	CC 40G	2/3	CC 40B	1
.50	CC 50R	1	CC 50G	1	CC 50B	1 1/3

for "yellow." It should be noted that in designating these filters, the decimal point is dropped.

The density of a CC filter is measured at the wavelength of maximum absorption. That is, the nominal value of a filter is equal to the peak net density effect it has relative to the light of its complementary color. Thus, the CC30Y will decrease the transmission of blue light by a 0.30 density increment. The nominal peak density values available in most Kodak CC filters include 0.025, 0.05, 0.10, 0.20, 0.30, 0.40, and 0.50. But these density values do not include the density of the gelatin in which the filter dye is coated, nor do they include the density of the support (acetone or glass) on which a filter may be constructed.

An allowance must be made for each filter's base density and ND factor if the desired overall exposure the film receives is to be maintained. For critical work, a high degree of accuracy is required. An appropriate densitometer equipped with a #106 visual filter can be used to evaluate each filter pack. This is quite necessary if two or more filters are used in the pack.

The following are some of the precautions to be observed when using these filters. Try to use the minimum number of filters that will produce the desired correction. Generally, the number should not exceed three, if definition is of major importance. Several filters together, over a camera or enlarger lens, may adversely affect definition and contrast by the scattering of light. Of course, definition is also affected by the condition of the filters. Keep the filters clean and free from scratches and other defects. Always handle all types of filters with clean white gloves and use the utmost of care.

From the example given in figure 5-10, it was determined that a 15 Magenta and 30 Yellow would be needed for correction, which would require the use of three filters in the pack: a CC05M, CC10M, and CC30Y. The total ND factor of this filter pack would amount to about a 0.15 density, requiring approximately one-half of an f/stop more exposure. This would have to be compensated for if constant exposure is to be maintained for the red sensitive emulsion or curve.

Once plotted, the color curves can be divided into three distinct areas of importance: the toe, straight line, and the shoulder. In color-correcting the reversal emulsion, the midtones (densities from 0.60 to 1.40) are normally the primary concern and represent the first area to balance, since most of the information (if properly exposed) would be represented within this range. The highlights would possibly be the secondary area (densities below 0.60) to balance. Under normal viewing conditions, the human eye is drawn to these areas and, with improper color balance, they would become readily apparent. The extreme shadows or D_{max} area is normally the last area of concern, because densities above 2.40 are hard to see under normal viewing conditions.

Color correction of reversal film is important because it is usually viewed and judged directly for density and color balance. Because of its relatively high contrast ($\gamma = 1.50$ through 2.50) and D_{max} characteristics, the reversal emulsion will generally have less exposure and color balance latitude when compared with the color negative emulsion. First generation negative film, on the other hand, has curves with long straight lines of relatively low contrast

($\gamma = 0.55$ through 0.85) which would mean more exposure and color balance latitude. Color negatives are seldom judged for color balance, only for printing characteristics. It is generally assumed that exposure and color balance can be corrected to some degree in printing.

From the preceding discussions on color corrections, several basic principles can be stated. Assuming that the tricolor reading of a sensitometric strip agrees with the visual impressions of the material being used, then the color curves should coincide over as much of their length as possible, particularly in the midtones (densities from 0.60 through 1.40). Normally, a single density level ($D = 1.00$) is chosen to balance the color curves. If the three curves coincide over their entire length, then the emulsion is considered balanced for use. However, if this is not possible, certain areas or density levels must be chosen to represent the most important elements of the scene. These areas are normally chosen and corrections made in the following order: the midtones, the toe, and the shoulders. Since integral tricolor readings are being used, the curves are represented in red, blue, and green on the graph. To make the necessary color corrections to the exposing filter pack, once the overall exposure is determined for the slowest emulsion layer, the rules are simple: (1) To move one curve to the right, add its complementary color and (2) to move two curves to the right, add the common additive color of their dye densities or the color of the third unaffected curve.

In the event the test is to be color corrected visually, the rules are quite different. When the test film is viewed with a standard light source, the desirability of some change in color balance may be apparent. The nature of such a change is determined by the predominant color balance of the film. Once this has been accomplished, the test is viewed through the complimentary filter of the predominant color.

The required filter adjustment involves subtracting a filter of the color of the overall predominance, if such filters are included in the system, or adding a filter that is complementary to the overall predominant color if the first filter does not exist. Table 5-2 may be useful in determining the desired filter adjustment.

No matter which method is used, the base densities of the CC filters must be considered in the modified filter pack. This is especially true if three or more filters are used and/or if a constant exposure is to be maintained. Always keep the pack to a minimum amount of filters.

In the foregoing discussions, implications were made that the emulsion layers of color film respond precisely to changes in effective exposure introduced by CC filters. As is often the case, however, some materials, because of the relationship of their spectral sensitivities to the absorbance of color compensating filters, do not respond exactly as might be expected. In addition, the overall effect on a reversal film may be different for colored objects in daylight from that of a neutral gray stepwedge in a sensitometer.

Also, it should be recognized that inaccuracies are inherent in the various areas of the system: film emulsion layer sensitivity, dye transmission characteristics, type of density measurement, densitometer filter response, visual response, printer light sources, and characteristics in the dupe stock. All these factors, and others, introduce complex variables whose total effect in the final product is not always predictable.

Experience will indicate certain situations where a correction factor will have to be employed. In spite of this, a sensitometric (rather than visual) approach to correction will produce consistently better results more quickly.

Exercises (854):

1. What can you determine from a family of curves?
2. What complications are introduced to the problem when color curves are not straight and do not coincide at all densities?
3. Why is the analysis of reversal materials simplified?
4. Since the goal in the analysis of reversal material is a visually neutral wedge, where should color correction begin?
5. Red, green, and blue are known as what kind of filters?
6. What is the purpose of color compensating filters?
7. How are the densities of CC filters measured?
8. List the three areas that divide a color curve?
9. In color correcting the reversal emulsion, which area is of prime concern to the technician? Why?
10. Color negatives are seldom judged for color balance but only for printing characteristics. (True or false)

TABLE 5–2

VISUAL COLOR CORRECTIONS FOR REVERSAL FILMS

233–157

REVERSAL FILMS

IF THE VISUAL APPEARANCE OF THE TEST IS	THE TEST SHOULD BE VIEWED WITH	ADD THESE FILTERS DURING EXPOSURE
YELLOW	BLUE	BLUE
MAGENTA	GREEN	GREEN
CYAN	RED	RED
BLUE	YELLOW	YELLOW
GREEN	MAGENTA	MAGENTA
RED	CYAN	CYAN

11. If three color curves coincide over their entire length, what could you say about that emulsion?

12. How are the color curves represented when using integral tricolor readings?

13. When a color test is corrected visually, the test is viewed through what filter of the predominant color?

855. Identify the characteristics of color negative material and tell how color negative material differs from color reversal material.

Color Negative Materials. Unlike the conventional or standard color reversal materials, color negative films are developed only once. After exposure to the original scene, the film is processed in a color developer where both the negative silver images and dye images within the emulsion layers are formed. This developing action is identical to the action that takes place in the color developer of the reversal process, and again, ideally the dyes are formed only where the exposed silver halide is being reduced to metallic silver.

The physical structure of the basic color negative tripack is very similar to that found in standard reversal films. However, because only one developer is used in the negative process, the final dye image formed in each emulsion will be complementary in color to those of the original scene. Also, the amount of complementary dye produced in each emulsion is governed by the exposure the layer receives. An increase in camera exposure will produce more dye, while less exposure will yield less dye in the final negative.

Since the final imagery of this material is a negative form of the original scene, the characteristic curves of the sensitometric test are displayed in the same as in the black-and-white negative evaluations. That is, the characteristic curves are plotted in such manner as to show the toe section to the left side of the graph in relation to the shoulder area of the curve, as seen in figure 5-13. As the exposure increases through the various steps of the original stepwedge, the density steps of the curve increase. Thus, the characteristic curve of negative material is displayed so produced density is always increased from left to right along the graph.

Since the color negative materials follow the same pattern previously described for reversal films, many of the same evaluation procedures apply. For example, using the 21-step wedge, the overall exposure of the test material is adjusted so that there are two steps (21 and 20) of the toe section of the curve recording the same density readings. This is done to verify that the base-plus-fog density of the test material has been achieved. In case of shift in color balance within the test material, the overall exposure must be adjusted to the slowest emulsion layer. In color negative material, the slowest emulsion will be represented by the curve that is plotted farthest to the right on the graph. Unlike the reversal curves, the faster emulsions of this material will appear up and to the left of the slower curve.

Once the overall exposure has been established for the particular film and the family of curves has been

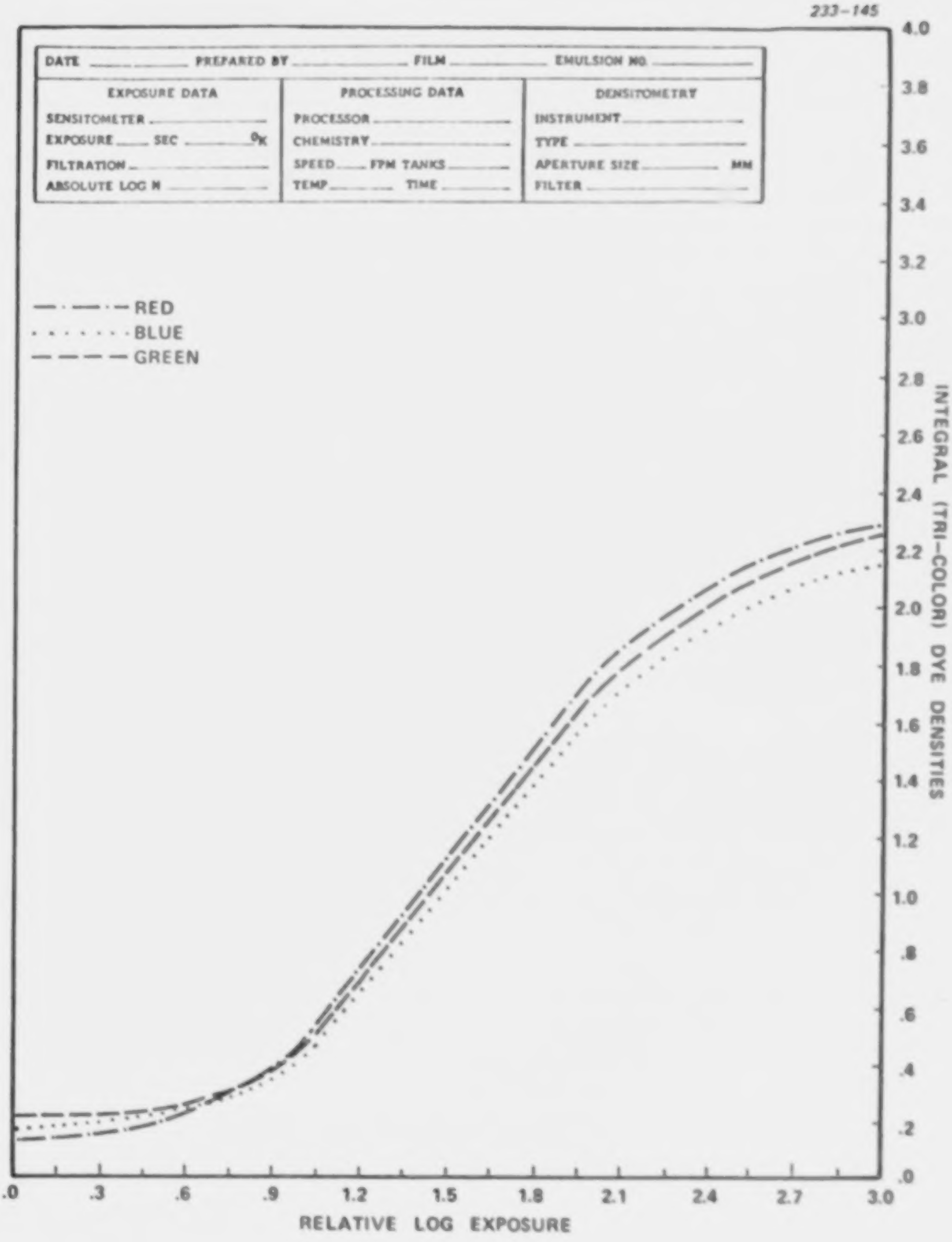

Figure 5–13. A typical family of curves from an aerial color negative film, type 2445.

constructed, the color correction can be determined. Since color negative materials are available having masked and unmasked properties, both types will be discussed briefly.

With unmasked aerial film, such as Type 2445, the three tricolor curves should coincide as much as possible over their entire length, as noted in figure 5-13. However, with color negative films utilizing the masking dye within their emulsions, it is not recommended that the family of curves be superimposed. In fact, with the yellow and reddish color couplers in this material, it is impossible to overlap all three curves and still maintain correct color balance. Therefore, with this film, all that is required is that the curves be essentially parallel (approximately of equal contrast) and about equally displaced laterally. Any further color corrections can easily be made during the printing stage of the process. Figure 5-14 illustrates a family of curves of a typical color negative film which has masking dyes incorporated within its layers. Figure 5-15 indicates the film has an out-of-balance blue density (D_b) curve. If this film were to be exposed in the camera system without color corrections, its top emulsion would have a higher sensitivity to blue light, which would cause the generation of too much yellow dye in this layer as compared to the dye produced in the other two layers. Therefore, the presence of the excess yellow dye can be attributed to the high densities produced by blue light.

In correcting the situation shown in figure 5-15 the D_b curve can be brought into balance by reducing the exposure to blue light. In the "subtractive" process, such a change involves placing a blue-absorbing (yellow) filter into the system. To determine the proper amount of yellow filtration that is required to bring the D_b curve parallel and about equally displaced laterally to the other two curves, the procedures are simple: (1) Locate, along the density axis of the graph, a point that is represented on the straight line (or very close) on all three curves; (2) horizontally from this point, determine the log increments between the D_g and D_r curves and place a point to the left of the D_g of the same increment units along the horizontal or log H axis; and (3) once this point is established, the distance between it and the D_b curve denotes the amount of yellow filtration that is required. From the example, the arrow indicates a length of 0.45 log H units, thus a total of 0.45 yellow filtration must be added. To hold the amount of filters to a minimum within the system, a CC40Y and CC05Y are utilized. Again, the ND factors of these two filters must be considered if the overall exposure is to be maintained for the film. Figure 5-14 shows the film in proper balance after the above filter corrections.

Similarly, out-of-balance green sensitve (D_g) and red sensitive (D_r) curves can be corrected in the same manner, using complementary magenta (CCM) and cyan (CCC) filters, respectively. Thus, the rule for correcting color balance of color negative material (masked or unmasked) is the same as in the conventional reversal films, since integral tricolor filters are used for both types of evaluation. To move one curve to the right along the log H axis, add the subtractive primary filter that is complementary to the color of the curve or the same color as the dye produced within the emulsion layer. To move two curves to the right, add the additive primary filter that is the common color of the two dye layers or the same color of the unaffected integral density curves. However, due to the characteristics of negative films, the filters added from visual determinations are quite different from those of reversal films, as noted in table 5-3.

Exercises (855):

1. How does development of color negative material differ from conventional or standard color reversal material?

2. How does the final dye image formed in the color negative tripack differ from standard reversal films?

3. The characteristic curve of negative material is displayed so that density increases in what direction along the graph?

4. In color negative material, how is the slowest emulsion represented on the graph?

5. How do the three tricolor curves react when using color negative films (such as type 2445)?

6. Between color negative materials (masked and unmasked), which will normally offer greater exposure latitude?

7. The rule for correcting color balance of color negative material (masked or unmasked) is the same as in conventional reversal film. (True or false)

856. State the characteristics of color infrared materials and state the effect of exposure on separate sensitive layers; also, state how to selectively control exposure with color compensating (CC) filters in order to effect color balance changes in the final transparency.

Color Infrared Materials. When a color transparency made with a standard or conventional color reversal film exhibits improper color balance, it is usually readily apparent and color correction is a relatively simple matter.

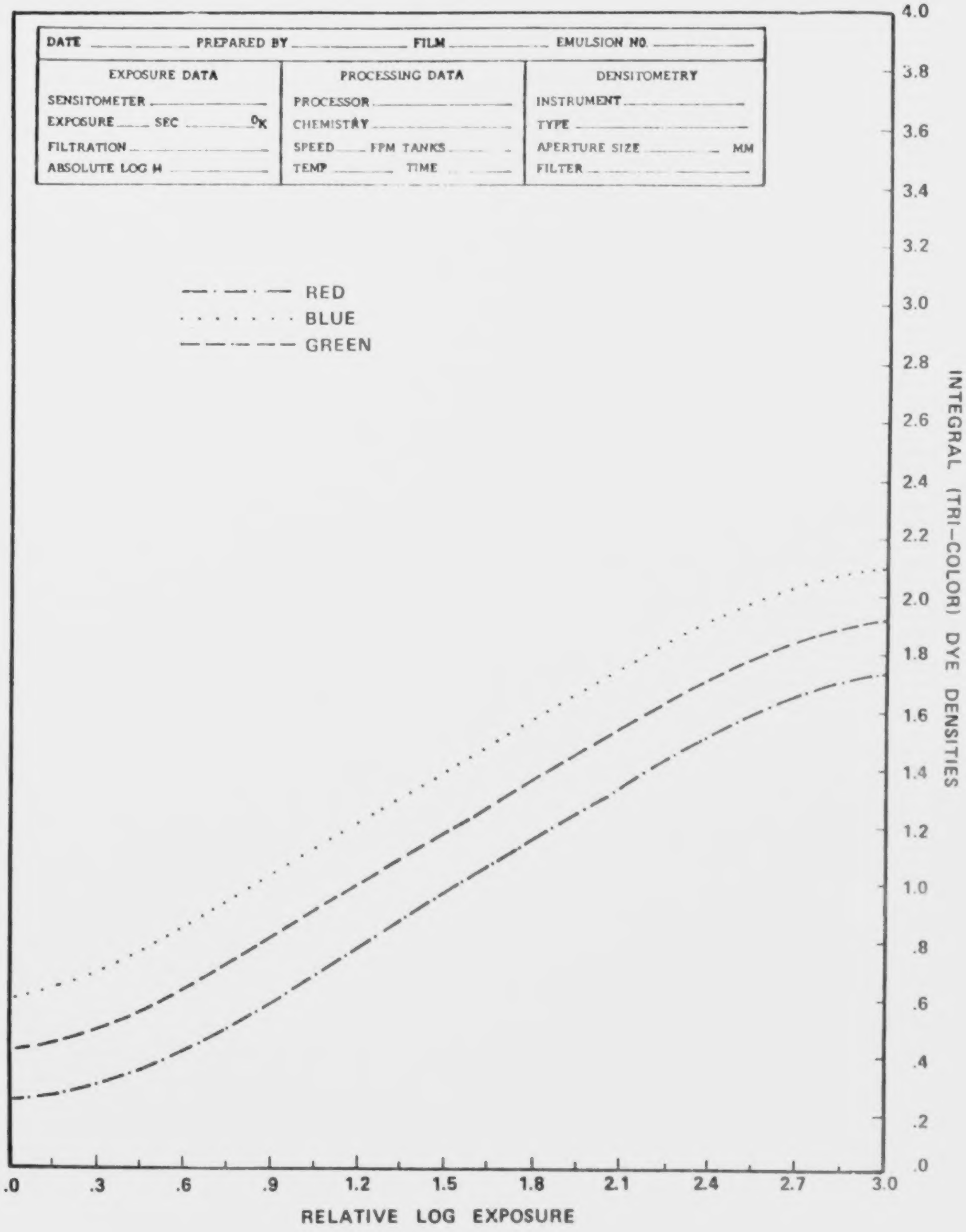

Figure 5–14. Sensitometric curves of a masked color negative film.

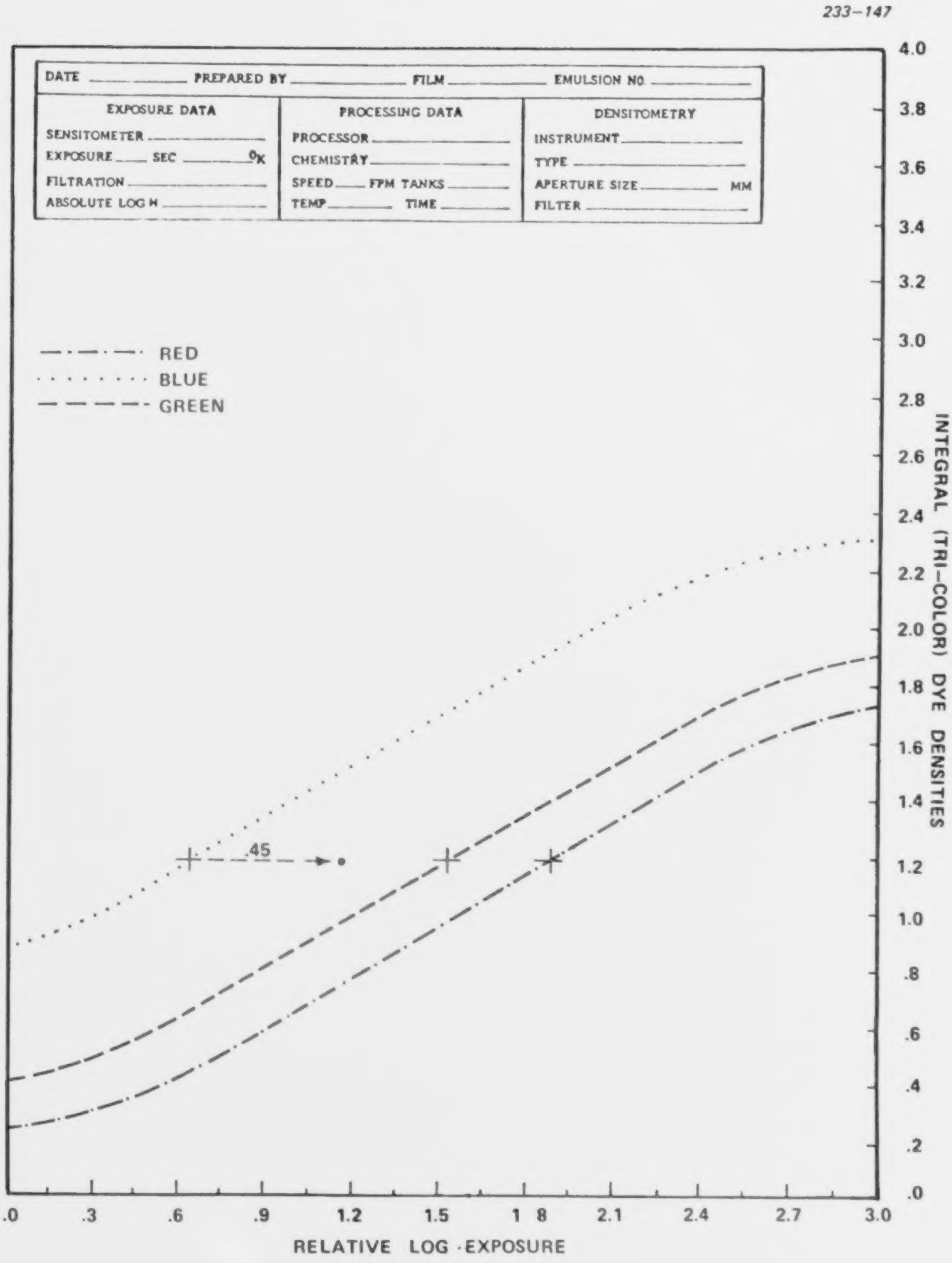

Figure 5–15. An out-of-balance masked color negative film.

TABLE 5–3

VISUAL COLOR CORRECTIONS FOR NEGATIVE FILMS

233–158

NEGATIVE FILMS

IF THE VISUAL APPEARANCE OF THE TEST IS	THE TEST SHOULD BE VIEWED WITH	ADD THESE FILTERS DURING EXPOSURE
YELLOW	BLUE	YELLOW
MAGENTA	GREEN	MAGENTA
CYAN	RED	CYAN
BLUE	YELLOW	BLUE
GREEN	MAGENTA	GREEN
RED	CYAN	RED

However, with the Ektachrome infrared film class, which incorporates an infrared-sensitive emulsion and involves unnatural color translations in other spectral bands, color correction becomes more complex. The purpose of this discussion is to explain the effect of exposure with color compensating (CC) filters in order to effect color balance changes in the final transparency.

The dye images on Ektachrome infrared film are not controlled by light of a color which is complementary to their spectral sensitivity, as in the case with conventional color films. It should be remembered that (like conventional reversal films) each dye layer in the final transparency is at maximum density without being exposed. Exposure to energy in a particular portion of the spectrum *reduces* the dye density in the layer sensitive to that energy.

In order to obtain optimum results in exposing and processing aerial Ektachrome infrared films (such as types 2443 and 3443), it would be beneficial to discuss some of their characteristics.

As noted in previous material, color infrared films must always be exposed in the camera system with a G–12 deep yellow filter, therefore, the sensitometric evaluations must be carried out under the same conditions. By utilizing this filter, each emulsion layer of the tripack effectively responds to only one form of radiation. Thus, the arrangement of the three emulsion layers of this film with the G–12 filter in place is as shown in figure 5-16. The infrared-sensitive emulsion controls the amount of cyan dye formed, and the green and red sensitive emulsion controls the yellow and magenta dye, respectively.

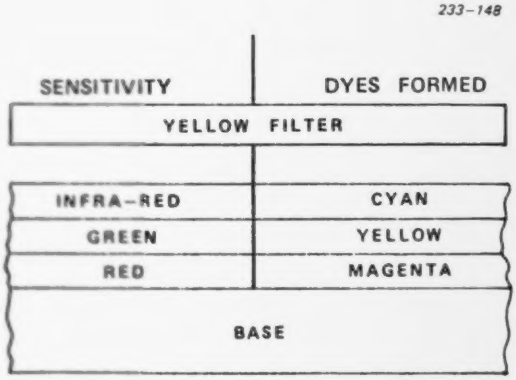

Figure 5–16. Characteristics of a typical color infrared film.

Some of the characteristics of this film have direct bearing on its ability to provide optimum differences within the original scene. For example, haze has been, and always will be, a problem in aerial photography. However, with this film it is possible to obtain good results even though extremely hazy conditions exist. This is possible because of two characteristics of this film. These are (1) the fact that the yellow filter is always used, thus the blue light is eliminated which contributes most to the degrading photographic effect of haze, and (2) because it has high gamma characteristics (noted from its sensitometric curves) which tend to offset the effect of haze in the green and red spectral regions.

However, because of the high gamma characteristics, this film has a rather short exposure latitude. For optimum results, the range is only approximately 1/2 f/stop of either side of the optimum exposure. If exposed beyond this range, some decrease in the information will occur, even though some compensation can be made by adjustments in the process.

Unlike normal color films in which the three emulsion layers are all or about the same speed, it is desirable that the

IR sensitive layer of infrared films be considerably slower than either the green or red sensitive layers. This sensitivity or speed difference is desirable because the reflectance characteristics of most living vegetation provide the exposing system with much more infrared energy than shows up in the green or red regions of the spectrum (fig. 5-17). Thus, if each of the three layers has approximately the same speed, the infrared-sensitive layer will constantly be overexposed and any variation of infrared reflectance in the scene will produce negligible cyan density changes. With the properly balanced cyan layer, the infrared exposure is recorded near or along the straight-line portion of the sensitometric curve; therefore, small variations in exposure will result in significant differences in the cyan density. This is extremely important if the film is to be employed either to detect the differences between two similar types of foliage or to reveal the presence of insect pests and plant disease at the earliest possible stage. These conditions often result in small changes in the infrared reflectance of the foliage; thus the film must be critically evaluated before and after the mission for proper determinations.

At the present time, the thought is that the sensitometric curves illustrated in figure 5-18 provide the best exposure and color balance for the greatest number of applications with this type of film. However, in some cases where special applications are required, a slightly different balance may be needed. Nevertheless, the positioning of the curves can be accomplished by filtration, which will be discussed later in greater detail. From the sensitometric curves shown in figure 5-18, it can readily be seen that the IR sensitive curve has been adjusted to yield a considerably slower speed than the green or red sensitive layer.

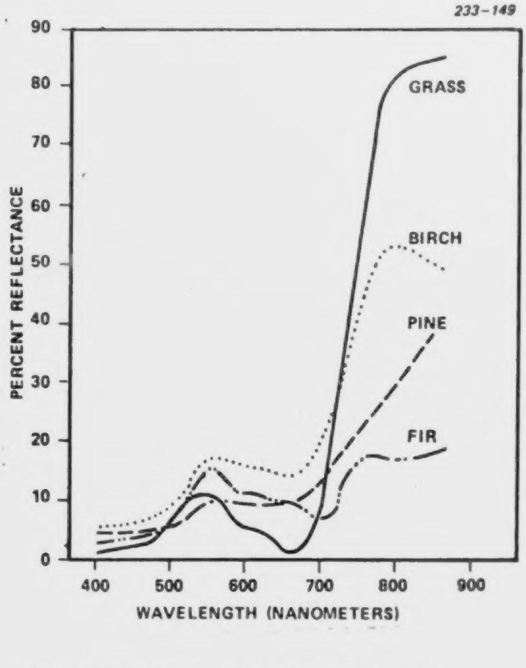

Figure 5-17. Reflectance of typical natural vegetation.

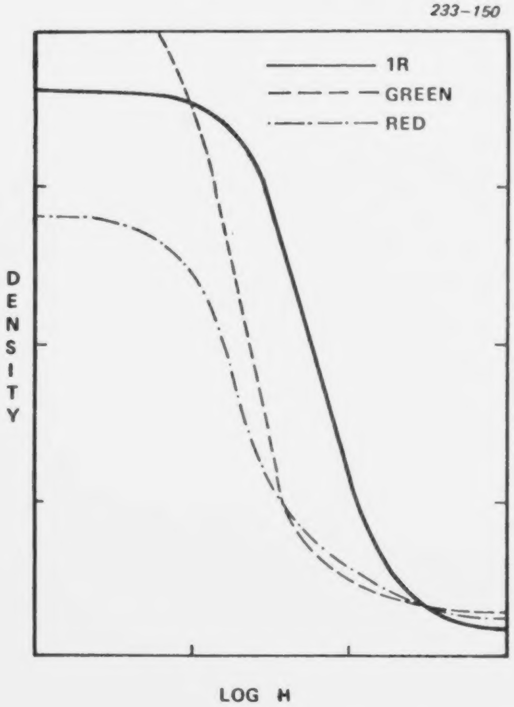

Figure 5-18. Sensitometric curves for typical color infrared reversal film.

In order to determine the optimum results with this film to provide maximum detectability for the particular condition or application, it is desirable to produce a series of transparencies with both the exposure and color balance varied systematically. From this series of transparencies, measurements can be made and related sensitometrically to the particular type of film. However, again it should be mentioned that the exposure that the film receives from the sensitometer must simulate the original exposing conditions as closely as possible.

To demonstrate how to find the approximate relative exposure required to produce the amount of dyes formed in each layer of the tripack, the following example is included. Four types of foliage were selected (grass, light green deciduous, dark green deciduous, and evergreen trees) and measurements from each were made from about 50 aerial transparencies. These measurements can be seen in figure 5-19, which shows the relative exposure produced by the four types of foliage. The exposure bar graphs are superimposed over the sensitometric curves to show the average individual layer densities which result when various types of foliage are given what is considered to be optimum exposure.

It can easily be seen that in all cases the exposure that the cyan dye layer receives is considerably greater than that of the other two layers. Also, it can be noted that both the

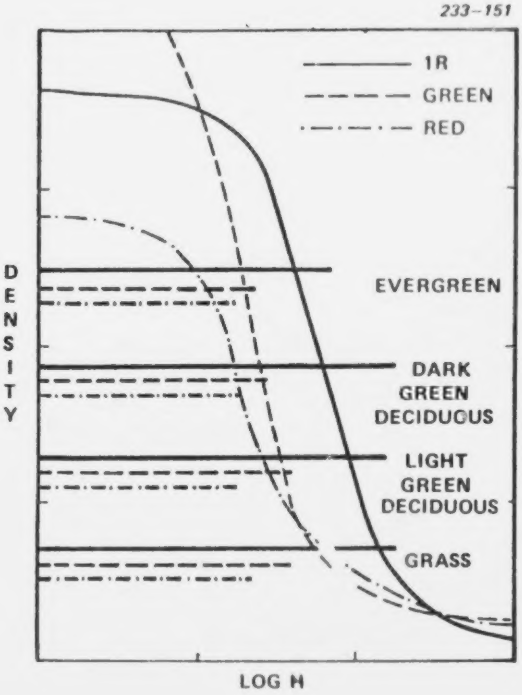

Figure 5–19. Bar graph showing relative exposure produced by four types of foliage.

grass and light green deciduous trees record a high degree of IR reflectivity, whereas the evergreen trees produce less exposure in all layers, and their infrared exposure relative to the green and red is less than that for the other types of foliage. The facts drawn from these evaluations agree with the reflectance curves previously shown in figure 5-17.

The situation shown in figure 5-19 helps to explain why the IR sensitive curve has been deliberately made so much slower than the other two curves. If the IR sensitive curve had been as fast as, say, the other two curves using the same camera exposure as shown in figure 5-18, most of the infrared exposure would be recorded in the toe or lower areas of the curve. Therefore, most of the foliage discussed, with the possible exception of the evergreen, would be recorded excessively red, and small differences in infrared reflectance would not be distinguishable. However, with the IR sensitive layer properly balanced, the infrared exposure for the various subject areas would be recorded well up on the straight-line portion of the sensitometric curve, and any small variations in these exposures will yield significant differences in the resulting cyan densities.

In evaluating this film on a sensitometer, it is necessary to consider the spectral energy distribution of the light source within the infrared region. Both the Eastman Model 101 and EG and G Mark VI can be used for these sensitometric evaluations. However, if the light source is composed of a tungsten filament lamp (as in the case of the Eastman Model 101), a filter such as the Corning 5900 glass filter must be used to meet daylight conditions. Although this filtration provides a satisfactory match for daylight within the visible spectrum, the radiation in the infrared region is considerably too high. An improvement in the infrared region can be attained by adding 1.0 mm of Pittsburgh 2043 glass to the filter pack. Also, when using the Model 101 sensitometer, a Corning 3966 glass filter can be utilized to absorb additional infrared and various thicknesses can be made to obtain any desired decrease in the speed of the IR sensitive layer. Thus, this filter can be very helpful, both in experimenting with color balance and for slowing the cyan layer of the film possessing an overly red balance. Tests performed with this filter of standard thickness have shown that it will change the color balance by approximately 1½ f/stop in the cyan direction. Seldom is more than half of the standard thickness of this filter required. However, since most of the sensitometers having a tungsten-filament light source are designed for duplication or process control, it is highly recommended the EG and G Mark VI be utilized for the evaluations of color-infrared film. This sensitometer has several advantages: (1) The light source requires no conversion filter since it is already balanced for daylight conditions, and also there is good response within the IR region, as noted earlier; (2) its time duration conforms closely to the shutter speeds of aerial cameras; and (3) Normally, only a few of the CC series filters are required to adjust the color balance. Therefore, the following information will be limited to the EG and G Mark VI and the CC gelatin filters pertaining to the evaluation of this film.

As previously discussed with other reversal films, the filtration alone can never increase the amount of energy received by a sensitive layer. If an increase is desired, the overall exposure is increased and filters are used to decrease the energy received by the other two layers to the proper level. Exposure can decrease or increase the density of dye layers proportionally. Filtration can *only* decrease the density of dye layers, but can do it selectively. The chart shown in figure 5-20 graphically displays the relationship of the exposing radiation to the resultant dye color for a conventional aerial reversal film (2448) and an infrared film (2443).

When each of the three dye layers is at maximum density, the final transparency will appear black. On conventional reversal color film, the image of an object reflecting green light will cause the density of the magenta dye to be reduced, leaving nearly total yellow and cyan dye densities. Together, these transmit only green light, thus reproducing the original scene.

On Ektachrome infrared film, a brilliant green object (that reflects no chlorophyl) will cause the yellow dye to be reduced, resulting in a (usually dark) blue reproduction. Living vegetation normally has a high reflectance in the infrared region, and this causes cyan dye to be reduced. If the total exposure were greater in the IR region than the green, the resultant image would be reddish (more magenta and yellow dyes and very little cyan dye). Should the sensitivity of the IR sensitive layer decrease relative to the other two layers, less cyan dye would be reduced. Thus, the transparency would appear too cyan and too dark.

233–152

SPECTRAL ENERGY IN THESE BANDS:	REDUCES THE DENSITY OF DYE OF THIS COLOR		LEAVING DYES OF THESE COLORS		WHICH TRANSMIT LIGHT OF THIS COLOR	
	IN 2448	IN 2443	IN 2448	IN 2443	IN 2448	IN 2443
(APPROXIMATELY)						
400–500nm (BLUE LIGHT)	YELLOW	••	CYAN MAGENTA	•• ••	BLUE	••
500–600nm (GREEN LIGHT)	MAGENTA	YELLOW	CYAN YELLOW	CYAN MAGENTA	GREEN	BLUE
600–700nm (RED LIGHT)	CYAN	MAGENTA	MAGENTA YELLOW	CYAN YELLOW	RED	GREEN
700–900nm (INFRARED)	•	CYAN	• •	MAGENTA YELLOW	•	RED

Figure 5–20. Comparative layer sensitivity of 2448 and 2443.

To determine and establish optimum color balance for this film, only a few of the Kodak color-compensating gelatin filters used in conventional color film evaluations can be used. There are only four CC filters that sensitometrically affect the individual layers of infrared color film. These are the cyan, cyan–2, blue, and magenta. The yellow, red, and green color compensating filters are of no particular value, other than for visual evaluation purposes to determine the desired color correction required. However, it should be remembered that with the four recommended color filters, each will have different absorption effects on the various layers of this film.

Most Wratten gelatin filters, including all of the CC series, are relatively transparent to radiation in the IR and near IR regions. For example, a CC40C filter has an effective density of 0.40 at 700 nm, 0.09 at 760 nm, and reaches a minimum of 0.04 at 800 nm.

Other CC filters have similar decreasing response within the IR region. The only exception is the cyan–2 series. These filters exhibit a high degree of absorption in the IR region as compared to the other CC filters. Thus, the cyan–2 series can be used to control the IR sensitive (cyan) layer. Generally, these filters are only used when a light source (such as tungsten) is emitting an excessive amount of infrared radiation or when a fresh batch of film is encountered that has a relative high-infrared sensitivity.

The results of these effects will yield a yellowish brown appearance in the final product, which can be corrected with use of these filters. However, such compensation necessitates a rather high increase in the exposure. For example, a cyan filter of 0.50 density requires an exposure increase of about 1 f/stop, while a CC50B (blue) filter requires approximately a 1⅓ stop exposure increase. Therefore, the lighter density CC filters are used for small changes in color balance. Also, it should be noted that a minimum number of filters is always sought for the filter pack to avoid degrading the image.

Normally, with color infrared films, the density level of the cyan dye layer can best be controlled by exposure changes. Changes in exposure, however, affect the density levels of the magenta and yellow dye layers as well as the cyan. With this film, the density level of the yellow dye layer can be held relatively constant by magenta filtration as overall exposure is increased. Similarly, cyan filtration will control the magenta dye layer, and blue filtration (magenta plus cyan) will control both.

Unfortunately, the effect of the CC filters is not isolated to a single film layer. Overlapping sensitivities permit magenta filtration to have some effect on the magenta dye layer (where it should control only the yellow dye, making it *relatively* more dense). Cyan filtration has a fairly substantial effect on the cyan dye layer (which is unwanted) as well as on the magenta dye layer, which it should control. The total effect is a rapidly diminishing return; it takes a substantial amount of filtration and corresponding exposure increase to affect even moderate changes in transparency color balance.

To assist the technician in obtaining the proper color balance with this film, table 5-4 is included. From the first part of this table, it can be noted that CC magenta filters shift the balance in the yellow direction. The balance can be shifted in the magenta direction with the CC cyan filters, or in the blue direction with the cyan–2 series. The second part of the table lists the various filters along with their approximate effects on the final product. Table 5-4 offers a starting point for sensitometric or visual evaluations. Again, the evaluations are normally based on the midtones while ignoring both the highlights and shadow areas. Using these tables as guidelines, the technician can balance the film to produce almost any result that is desired.

There is a tendency to consider infrared radiation equivalent to that of heat and to expect this film to photographically record differences in temperatures. Actually, experiments have proven this to be somewhat

TABLE 5-4

·INFRARED COLOR FILMS

233-159

INFRARED COLOR FILMS

Visual Appearance

This filter	will shift the color balance from	to
Cyan	Green	Magenta
Cyan-2	Yellow	Blue
Blue	Cyan	Red
Magenta	Blue	Yellow

Sensitometric Corrections

If the overall appearance of the IR film is	and this CC filter gives the desired appearance	the approximate correction during exposure will be
Blue	05Y	025M
	10Y	05M
	20Y	12.5M
	30Y	17.5M
	40Y	22.5M
	50Y	30M
Green	05M	025C
	10M	05C
	20M	12.5C
	30M	17.5C
	40M	22.5C
	50M	30C
Cyan	05R	025B
	10R	05B
	20R	12.5B
	30R	17.5B
	40R	22.5B
	50R	30B

untrue, since two factors (camera lens and the film itself) make it virtually impossible to use this film to record and detect temperature changes by means of conventional photography.

As previously discussed, the infrared region extends far beyond the visible region and eventually merges into heat waves and into radar and radio waves. If compared on the electromagnetic spectrum, the infrared region occupies an extremely larger area than that of the visible region.

Although the infrared radiation extends far out, it is only the region quite near the visible spectrum (a range from 700 to about 1350 nm) that is photographically actinic (or active). This range, simply stated, represents the area in which radiant energy is capable of producing a chemical change directly on a photographic emulsion.

In fact, in ordinary infrared photography, the film is sensitized to include only the range from 700 to 900 nm. Only in special photography, such as astronomical or other scientific photography, is the film hypersensitized to include up to 1350 nm. If the film is hypersensitized to include 1350 nm, special storage conditions are required. Also, the extremely slow speed also makes it impractical for use in aerial cameras. In addition, the glass lenses employed in most camera systems are limited by their transmission factors. Therefore, these films are sensitive only to the near infrared region, up to approximately 900 nm, and are not thermal or heat detectors. Tests performed with this film have shown, with no other type of radiation present to affect the film, that an object must be heated to 650°F with an exposure of f/2.0 for 15 minutes before an image is recorded by the infrared sensitive layer of the film. Therefore, the film will not record temperature differences at our environmental temperatures.

The recording of nonphotographic or thermal images produced by nonactinic (passive) infrared radiations is called indirect infrared photography. This type of photography involves more complex equipment than normally employed in camera systems. This does not mean, however, that the final imagery is not displayed on film (in fact, in most cases, film is used), but the means of obtaining the image is quite different. For instance, with indirect photography, the problem is solved by using the linescan principle similar to that developed for sidelooking airborne radar sensors. As noted in figure 5-21, a multisided rotating scanning mirror (rotating prism) scans a narrow strip of the ground in successive sweeps. The IR or heat radiation is picked up from the image by a scanning mirror and reflected by a series of surface reflection mirrors to the parabolic lens. Due to the similarity between IR and light, the parabolic lens focuses only the IR energy on the detector. The detector converts the IR energy to an electronic signal and feeds the pulse to a data processing unit. The data processor has several functions, one of which is to amplify the signal and feed it to a glow modulator or cathode-ray tube (CRT). These units convert the signal from an electronic pulse to an electronic beam (or light signal) which is flashed across the face of the cathode-ray tube as a scan line. At this point, a lens can be employed to concentrate the imagery to the recording medium, such as film. The film is moved across the face of the lens at a speed corresponding to the ground speed of the aircraft. A series of modulated, light, continuous linescans are recorded onto the film to create a composite called a thermograph, which can be recorded and visually displayed by conventional means, using black-and-white or color films.

From the above information, you can see that recording methods fall into two broad categories: one, involving direct photography, uses film with a conventional camera system, and the other, the indirect method, uses complex equipment which produces an image that can be transferred onto ordinary film. This chapter deals only with the direct method, but the indirect method is briefly presented to distinguish between the two and to dispell any previous

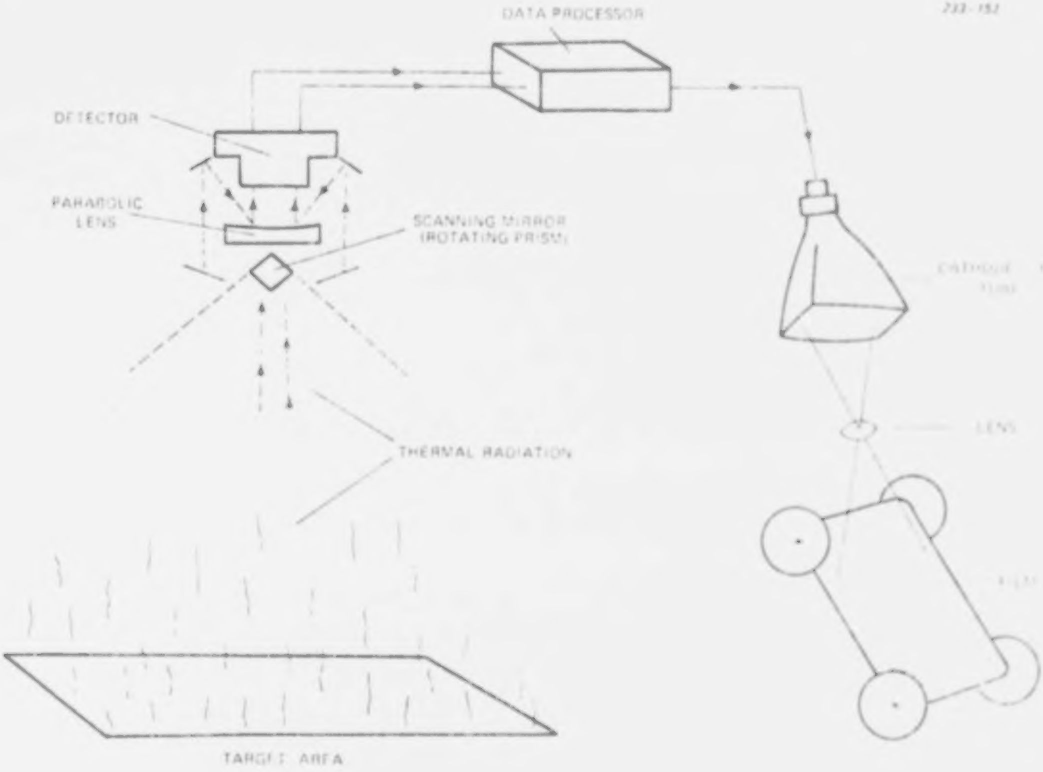

Figure 5-21. Basic illustration of recording imagery utilizing indirect infrared photography.

beliefs that may associate heat or thermal recording to conventional infrared films.

The above explanations should not be taken to imply that this film does not react to changes in temperatures. Just as in all photographic emulsions (especially color), infrared films are highly receptive to temperature changes as well as aging. For instance, if exposures are made when the film is very cold, some loss in speed occurs, along with a shift in color balance in the cyan direction. These effects are not significant in low-altitude reconnaissance, but for high-altitude work, marked changes may result, especially with unheated or partially heated cameras. Sensitometric tests have shown that if this film is exposed at −40°F, the speeds of the green and red sensitive layers are decreased by 0.20 in log H units and the infrared sensitive layer is decreased by 0.60 increments.

In addition to the effects of temperature, tests have revealed that the film also changes with aging. As the film ages, the infrared sensitive layer tends to decrease in speed and the speed of the green sensitive or yellow layer is increased slightly. Again, the color balance shift would be in the cyan direction. If the film is stored at room temperature, the infrared-sensitive layer will rapidly lose its sensitivity and pass the point of optimum color discrimination. In fact, tests performed on the other SO−180 film indicated a total loss of its IR layer in less than 30 days, due to improper storage. However, this effect can be considerably reduced by refrigeration, or almost eliminated by storing the film in a freezer under subzero conditions. As with all color films that must be stored for extended periods of time (6 months or more), it is recommended that each roll sealed in packages by the manufacturer be kept at 0° to −10° F for optimum quality.

In fact, to ensure optimum results in the final product, it is highly recommended that the individual lab have complete control of all film. This applies to the storage, testing, and processing of all film (especially color materials). Since color films are so critical, sensitometric evaluations should be performed on each roll before they are loaded in the camera system. By locally evaluating the film, the quality control technician can determine its present condition and make the required changes in speed and color balance. Once these and other values are determined, corrective action can be made by the personnel before the mission is flown. An additional advantage for testing the film before flight is that the mission would be processed in the same processor/chemistry conditions, thereby reducing many variables.

Exercises (856):

1. What filter is used to expose color infrared film in the camera system?

2. It is possible to obtain good results with infrared film under what weather conditions?

3. What exposure latitude would you expect from a film that has high gamma characteristics?

4. Why is it desirable that the IR sensitive layer of infrared films be considerably slower than either the green or the red sensitive layers?

5. What conditions should prevail when the infrared film receives the exposures from the sensitometer?

6. When exposing IR film, what layer seems to receive a considerably greater amount of dye?

7. In evaluating the IR film on a sensitometer, what must you consider of the light source?

8. Between the two sensitometers (Eastman Model 101 and the EG and G), which is highly recommended for infrared film evaluations?

9. Although exposure can decrease or increase the density of all dye layers proportionally, what does filtration do?

10. What CC filters have a high degree of absorption in the IR region?

11. The infrared radiation that is photographically actinic (or active) is within what range?

12. What recommendation can you make to insure optimum results in the final product?

Answers for Exercises

CHAPTER 1

Reference:

800 – 1. A sensitometric processing machine must be capable of precision operation. It must be able to give the same kind of development, at the same temperature, and with the same agitation, time after time.

800 – 2. These agitators can be (1) a rocker, (2) an oscillating film carrier, (3) a moving vane, (4) a rotating paddle, or (5) a nitrogen gasburst diffuser.

801 – 1. Set aside carefully pretested and certified chemicals.

801 – 2. Cross-check each chemical batch with the previous batch.

802 – 1. Supply the sensitometric processor with processing solutions capable of results identical to those obtained with seasoned solutions in the processing machine. When the chemicals have been matched, make sure that the physical factors, such as time, temperature, and agitation, in the sensitometric process also match with the production process. Sensitometric strips are processed right along with the production film in the processing machines.

802 – 2. Run a series of tests. Insert as many sensitometric strips as possible with every production run and record the data for each strip. Do this over a sufficiently long period to enable you to arrive at a normal distribution. Then make periodic observations based on these sensitometric tests.

802 – 3. Observe your sensitometric test strips and examine them with negatives that they are supposed to control. Look for the contrast in the developed negative. If you decide that the greatest (D_{max}) and the least (D_{min}) contrast lie closer to the centerline of your control chart, then set the acceptance limits to correspond with the acceptable gammas. From this point on, keep the product with a gamma that lies within your limits and reject any product whose gamma lies outside these limits. Retain the original 2-sigma limits so that you can determine whether or not the process is operating normally.

802 – 4. You can minimize such counteracted errors by monitoring chemical concentrations as well as mechanical and physical control to include agitation, temperature, and time.

803 – 1. You must rely upon a control film stock.

803 – 2. You establish the standards for this control emulsion after repeated sensitometric tests of many film samples. When you find the emulsion that gives you the results you want, set it aside for test purposes.

803 – 3. To hold one group of variables constant while studying the changes that may occur when using another group of variables.

803 – 4. Like normal film stock, control film stock is kept refrigerated under 50°F. and 50 percent RH conditions.

803 – 5. Errors in control strips occur when one or more of the following are present:

a. Complete film stability cannot be achieved even though cold storage retards deterioration from natural aging.

b. Growth or decay of the latent image may occur due to normal storage conditions or lengthy storing.

c. Variations in uniformity and sensitivity of films are inherent.

804 – 1. The exposure produced on the film in a sensitometer depends upon the intensity of the light source, its distance from the film, the time of exposure, and the amount of absorption .of light caused by the various optical elements, such as glass plates, mirrors, filters, and the step-tablet modulator.

804 – 2. The type IB sensitometer is an intensity-scale, nonintermittent instrument using stepped exposures.

804 – 3. Changes may be detected by comparing an exposurer made by the sensitometer light source against that made by a calibrated standard lamp. When processed, any difference in the sensitometric strip will appear as a difference in film density.

804 – 4. The initial calibration of a sensitometer depends upon the light-gathering power of its lens or optics.

804 – 5. Heat or temperature plays an important role since all film-sample exposures should be made at the same temperature; otherwise erroneous log H values, determining film speed, may result.

804 – 6. One instrument uses an incandescent light source and can produce exposures of relatively long duration, while the other instrument produces extremely short, highly actinic exposures. Having both types enables you to produce test strips that conform quite well to most practical situations.

805 – 1. To establish processing control, the flash duration that closely approximates the exposure given the film to be processed must be chosen.

805 – 2. Photographic speed, range of tone, contrast, color balance, fogging, and age.

805 – 3. Neither the intensity nor the color of its light source deteriorates with time.

806 – 1. The sensitometer is a type 1B instrument designed for both the evaluation and control of photographic material.

806 – 2. The plane of exposure is semicircular and is illuminated by a rotating tube.

806 – 3. From 1/20 to 1/100 second.

806 – 4. Partial pressure will cause the instrument to chatter.

807 – 1. You can establish a control on a densitometer by using one or more steps of a calibrated step wedge. Over a period of 20 days, the densities measured by your instrument should not show any shifts in levels or stability.

807 – 2. The precision control level is indicated on the chart as a single line so that any check reading may be checked against the level. Allowance or tolerance can be made by indicating 3-sigma limits to either side of the precision control level.

807 – 3. There are two advantages of using a linear scale: (1) with its evenly spaced graduations, the scale is easier to read, (2) it can be read with greater accuracy than nonlinear scales.

807 – 4. In conjunction with an internal calibration reference, the calibration control is adjusted until the up-scale density is read on the meter.

807 – 5. Run through the entire operating procedure to reset the densitometer whenever necessary to ensure that the instrument is performing according to the factory specifications.

807 – 6. Each instrument has a calibrated ''standard'' step tablet to assure the calibrations reference control.

807 – 7. In accordance with the troubleshooting chart shown in table 1-1, the low output of a null-type instrument will cause poor precision of density readings. The lamp should be replaced.

808 – 1. This may be done by plotting the density of each step in a test strip in relation to the exposure needed to provide that density.

808 – 2. Because the graph records log values, the meter-candle unit can be changed to log value and then added to the log value of the exposure time in seconds. An alternate method is to multiply the meter-candles by the exposure time and then convert the product to its logarithm value.

808 – 3. The 21-step wedge usually has a 0.15 log difference between each step, whereas the 11-step wedge uses a 0.30 log difference between each step.

808 – 4. The following information is usually shown: Density (vertical axis); log H (horizontal axis); film or material being tested; developer and development used; gamma obtained.

809 – 1. You can determine any film's speed and latitude as well as the useful exposure range of various emulsions.

809 – 2. As exposure increases, the density decreases even more.

809 – 3. Decreasing the exposure will increase the length of the toe's flat portion and shift the entire straight-line portion of the curve to the right.

809 – 4. The threshold is the point on the toe where the density first becomes perceptible.

809 – 5. From the straight-line portion, you can either choose an exposure for a particular density or you can predict the density for a preselected exposure.

809 – 6. The amount of space between two points relies on the amount of additional light or decreased light between the first and second exposure.

809 – 7. The distance between the points would stay the same, but the two points would move to the left along the log H axis.

809 – 8. In its improved form, the gamma formula is useful in determining gradient and angle of the straight line.

809 – 9. Development contrast is better represented by the H and D curve because gamma pertains only to the straight-line portion of the curve.

809 – 10. Although the correct proportional reproduction can be obtained by a gamma value greater than or less than 1, the object brightness scale of the former will be long or expanded, whereas the latter will be short or compressed.

809 – 11. A flat toe means that the silver halides have not been exposed long enough to make them developable.

CHAPTER 2

810 – 1. Latitude value is important because it determines the maximum object contrast. This contrast may be rendered proportionally between density and log exposure on a particular film that is to be processed under specified conditions.

811 – 1. Start at a point on the characteristic curve where the density is 0.10 above the base-plus-fog density and continue over a log H range until a point equal to Δ log H of 2.00 is reached. A value equal to the tangent of an imaginary line drawn between these two points determines the contrast index. In the form of a formula, the contrast equals tan α.

811 – 2. The nomograph.

812 – 1. The methods for determining film speeds are: (1) Method A, (2) Method B, (3) Method C, (4) Method D, (5) Method E, and (6) Method F.

812 – 2. Photographic emulsion speed indicates a measure of the emulsion's sensitivity to a radiation.

812 – 3. In military aerial reconnaissance it is well known that much more significant intelligence data is contained in the shadow areas of a photograph. For this reason it is customary to expose aerial reconnaissance films for the shadows.

812 – 4. By experience or observation.

813 – 1. Because of the masking.

813 – 2. Vertically.

813 – 3. The processing test materials should conform to production practices.

813 – 4. Parallel.

813 – 5. The green sensitive layer.

813 – 6. Reciprocal.

814 – 1. Visual density type.

814 – 2. Film speed values are based on the minimum exposure necessary to produce minimum density.

814 – 3. The using organization.

815 – 1. Exposure and processing.

815 – 2. The measured densities of the original negative (minimum-maximum).

815 – 3. Correlating exposure and processing.

816 – 1. The total densities of the original negative based on the latitude of the film.

816 – 2. A desired minimum of 0.40 and a desired maximum of 1.80 densities.

816 – 3. The toe of the process remains relatively constant, while the gradient of the shoulder decreases.

817 – 1. You can, thereby, select the appropriate processing time to obtain a desired gamma and show the slight differences that exist in base-fog levels at various processing times.

817 – 2. More curves provide additional points and hence increase the validity. Five points will give reliable results; three points is the minimum requirement.

818 – 1. It is useful in process control. The data graphically displayed on this kind of chart reveals the particular time and temperature needed when you are using a specific developer-film combination to obtain a particular gamma.

819 – 1. In such cases, tone reproduction consists of visual evaluation of the product.

819 – 2. The tonal relationship between subject and reproduction.

819 – 3. There are four quadrants to a tone reproduction diagram. They are: Quadrant I—it is used to plot negative densities, D_n. Quadrant II—it is used to plot positive material densities. Quadrant III—its 45° line is used to transfer plots of the negative and positive densities to the next quadrant. Quadrant IV—it is used to plot the tone reproduction curve.

819 – 4. With conventional cameras and average scenes.

819 – 5. The scene luminance scale is the ratio of maximum to minimum luminance values of the scene.

819 – 6. The luminance scale of most scenes is measured by using a telescopic luminance photometer with a small-look angle and directing its receptor at the various luminances in the scene.

819 – 7. The object on the focal plant of a camera is affected not only by image-forming light originating at the subject but by non-image-forming (flare) light within the camera.

819 – 8. The effect of flare is greatest in the thin areas of a negative and least in the areas of maximum density.

819 – 9. The flare image increases the illuminance evenly over every portion of the camera image and, by so doing, reduces its contrast. The presence of flare light has the effect of compressing the illuminance scale of the image.

819 – 10. Since flare light is present in any camera and has an effect on the image, it is desirable to include a flare curve in our tone-reproduction diagram.

819 – 11. The shape characteristics of the toe and the straight-line portions.

819 – 12. It is usually necessary to suit the positive material to the negative rather than attempting to produce a negative from a particular positive material.

820 – 1. You must consider the conditions of the scene, the negative material being used, the flare light present in the camera, the exposure given and the kind and amount of processing given the negative.

820 – 2. The tone reproduction quadrant would contain a straight line of 45°.

820 – 3. Because density increases in a downward direction in quadrant IV.

820 – 4. The situation can occur when two different cameras are used to photograph the same scene and can have differences in flare light.

820 – 5. The principle of tone reproduction analysis can be applied to optical systems, other than cameras, wherever flare light is present or wherever changes in exposure and choices of material are possible.

821 – 1. Yes. The original negative is a priceless item because it is acquired through careful planning and at great exposure.

821 – 2. Tone reproduction diagrams are of considerable value in controlling the process of multiple generations of film, just as they are of value in the production of positives from negatives.

821 – 3. The effects of camera flare and atmospheric haze.

822 – 1. The trigradient tone reproduction uses the tones present in the original negative as a basis for computing the exposure and processing parameters of negative duplication.

822 – 2. By a calibrated step wedge.

822 – 3. One-for-one, as shown in figure 2-19.

822 – 4. The laboratory has three criteria: (1) to reproduce the full scale of the original subject; (2) to provide tonal discrimination between specific areas (detail) with particular emphasis on correcting tonal compression due to inadequacies of the original medium; (3) to provide an increase in informational capacity through an appropriately customized reproduction system.

822 – 5. It will fulfill the first criterion that is to reproduce the full scale of the original subject.

822 – 6. Printing the negative on a material capable of delivering a high gamma.

822 – 7. The scene represented in figure 2-23 requires a processing to a low gradient so that the range of tones can be accommodated on the straight-line portion of the printing material.

822 – 8. The initial step is to determine the sensitometric characteristics of the emulsion to be used.

822 – 9. You use an average gradient (G) between the densities 0.30 and 1.80 (fig. 2-24).

822 – 10. A calibrated step wedge.

822 – 11. They use an automatic recording densitometer, such as the "Quantascan" (fig. 2-26).

822 – 12. The reason for this limiting action is that various emulsions and bases transmit light to varying wavelengths of the spectrum; therefore, if the spectral composition of the light is altered by the film base, then the reproduction will be affected. This effect is multiplied by each succeeding generation and, ultimately, the response will be totally unpredictable.

822 – 13. It is valid only if conducted according to the same procedures under which the original tone reproduction diagrams were drawn.

823 – 1. It can provide solutions to tone control problems.

823 – 2. In those cases when information for quadrant I is available, the trigradient system uses quadrant II as a starting point.

824 – 1. It is used to produce a composite picture of an area where relative, rather than absolute, positions of the terrain features are desired.

824 – 2. It is used for map-and-chart revision and as map substitute.

824 – 3. (1) Prepare a photo index.
(2) Procure a sufficient amount of photographic paper for the entire job.
(3) Procure a sufficient amount of photographic chemistry for the entire job.

824 – 4. (1) Overlap 60 percent.
(2) Sidelap 30 percent.

824 – 5. The master print must have maximum detail in all areas, normal or slightly less than normal contrast, and a uniform tone and density.

824 – 6. The master print.

CHAPTER 3

825 – 1. One way is to give the emulsion a series of reciprocally varied constant energy exposures or plotting families of constant density curves based on the log IT vs. log I.

826 – 1. Speed and contrast.

827 – 1. At high intensities, the log IT value increases as the temperature decreases. At low intensities, the log IT value increases as the temperature decreases. At low intensities, the log IT value decreases until a minimum is reached and then increases.

827 – 2. This phenomenon is useful when it is necessary to make long exposures to low-intensity light sources. By lowering the temperature of the photographic material, shorter exposures would be required.

828 – 1. A rather uncomplicated reciprocity failure variation.

828 – 2. An emulsion is troubled by reciprocity failure (1) when exposing film in extreme heat or cold, since reciprocity failure varies with temperature; (2) when using deep cutting filters, since reciprocity varies with wavelength; and (3) when exposing multilayer or color film because of variations between emulsions.

829 – 1. Color shifts present a greater problem than changes in overall speed and contrast.

829 – 2. Adding the proper color filter and increasing the exposure level.

830 – 1. When the exposure to a series of intermittent units of light is given, the resultant density is different from that which would be produced by a continuous exposure of the same energy.

830 – 2. An effect equal to that of the continuous exposure.

CHAPTER 4

831 – 1. Gray-scale exposures.

831 – 2. The basic light in a sensitometer is usually a tungsten lamp that operates at 2850 K, and the use of photometric filters can raise the color temperature to approach daylight.

831 – 3. The two principal approaches are: (1) exposures are made through sharp-cutting filters so that one layer of the film is exposed at a time, and (2) all three layers are exposed simultaneously to yield a neutral response when viewed together.

831 – 4. It must be nonselective or absorb the same amount of light between the range of 350 nm and 700 nm.

831 – 5. (1) Operating time and (2) measurement of illuminance.

832 – 1. Unlike conventional film with only a single emulsion layer, color emulsion has three layers of emulsion so that vertical adjacency effects are introduced by the diffusion of developer byproducts.

832 – 2. No. Such methods are neither economical in time or money, nor are they sufficiently accurate to warrant doing them.

832 – 3. Agitation must conform to practice through all stages of the process, since minor changes in agitation can have pronounced effects on the developed image.

832 – 4. It is necessary for you to accumulate a certain amount of data. Sensitometric strips are processed in various parts of the tank and at various times during the processing day. This is done over an extended period of time so that all the characteristics of the process, based on statistical evaluations, are determined, and control procedures can be established.

833 – 1. (1) Specular densities and (2) diffuse densities.

833 – 2. (1) Integral densities and (2) analytical densities.

833 – 3. (1) Printing densities, (2) colormetric densities, (3) luminous densities, (4) three-filter densities, and (5) spectral densities.

833 – 4. (1) Analytical spectral densities (ASD), (2) equivalent neutral densities (END), and (3) equivalent neutral printing densities.

834 – 1. The light modulation of a particular color is dependent on absorption, which is itself determined by the number of absorbing molecules in the dye used.
834 – 2. Beer's law would be used to determine the absorption properties based solely on molecule concentration.
834 – 3. The additivity rule of color mixture requires you to add the individual dye, D λ: therefore, the END D λ would be 0.83.
834 – 4. With a constant ratio, 1.93, the D λ at 480 nm would be 1.93 × 0.69 = 1.33.
834 – 5. Under the log D rule, the equation would be set up as log 1.45 – log 0.75 = antilog of 1.33.

835 – 1. Most densitometer illumination is modified to compensate for the spectral conditions and to reduce the effects of infrared radiations.
835 – 2. The mercury-cadmium arc lamp.

836 – 1. To limit the spectral composition of the illumination to the narrow wavelength bands required for special measurement.
836 – 2. They should be stable. They must be able to withstand the heat, humidity, and the radiant energy to which they will be subjected.
836 – 3. The red with a dominant wavelength of about 646 nm, a green filter whose wavelength peaks at 545 nm, and a blue filter with a dominant wavelength of 460 nm.

837 – 1. To modify the spectral characteristics of the illumination.
837 – 2. The dispersion of light breaks up the wavelengths into a spectrum from which only selected wavelengths pass through a narrow slit.

838 – 1. Wedges are used to reduce the intensity or change the color of the measuring light.
838 – 2. A wedge is a light absorber whose density gradient is continuously variable, usually linearly, with respect to distance along the wedge.

839 – 1. The eye.
839 – 2. Since fatigue tends to affect the accuracy of photometric and colorimetric matches, you should not use visual instruments for extended periods of time.

840 – 1. The information is transmitted to a measuring or recording device by amplified electrical signals.
840 – 2. The scale is divided into logarithmic increments to yield density measurements, and the compressed graduations at the high-density end are often misread by inexperienced or tired operators.

341 – 1. Densitometers and spectrophotometers.
841 – 2. Some densitometers are equipped to provide direct signal readout which can be channeled to typewriters, punched cards, or tape. These densitometers are recommended for processing large quantities of data.

842 – 1. Diffuse transmission density.
842 – 2. You should make new corrections and recalibrate the instrument.

843 – 1. The direct-reading densitometer is usually calibrated by measuring the output radiation with no sample in place. The density reading is adjusted to zero, and all density readings following are made against that reference. The light in a null instrument is divided by a beam splitter. One half of the light passes through the sample, and the second half takes another path to reach the receptor. Densities are read from a scale connected to the attenuator.

844 – 1. Yes, if they are equipped with red, green, and blue filters for integral color-density measurement.

845 – 1. The operation of the analytical color densitometer is based on the principle that the absorption of the dyes in the film sample can be matched by the absorption of some combination of the three wedges, each of which contains varying known amounts of dyes that comprise the sample.
845 – 2. The beam of light on the left passes through the sample, whereas the beam of light on the right passes through the three wedges.

846 – 1. It is important because all materials should be able to reproduce a scale of neutral densities so that you can determine whether or not the component colors are present in the correct amounts.
846 – 2. Subtracting the END of the dye wedges from the visual density of the neutral wedge will give you this information:

	Magenta	*Cyan*	*Yellow*
Wedge	0.87	0.87	0.87
Dye ENDS	–0.05	–0.25	–0.45
ENDS of film	0.82	0.62	0.42

CHAPTER 5

847 – 1. Standardized quantitative information which can be measured, compared, displayed, and communicated.
847 – 2. The characteristic or sensitometric curve and the control chart.
847 – 3. The control chart.
847 – 4. The sensitometric curve.
847 – 5. The absolute curve is required.
847 – 6. Illuminance; time.
847 – 7. In meter candles.
847 – 8. The log of exposure in meter-candle-seconds (MCS).
847 – 9. 0.30.
847 – 10. The log of exposure at the original stepwedge and the density of the maximum step of the original stepwedge.
847 – 11. Each curve represents the exposure versus (dye) density relationship for approximately one-third of the visible spectrum.
847 – 12. The yellow dye absorption within the emulsion as a whole.
847 – 13. We are reading integral densities. Each curve is plotted in the same color as the filter used in the densitometer to obtain the data. Upon completion, the family of curves will be the primary colors: red, green, and blue. Each color density will represent the total effect or opacity of the complementary dye absorption within the emulsion as a whole.
847 – 14. The three color curves are superimposed as a single curve.

848 – 1. A decrease in density.
848 – 2. The shadow areas of the original scene.
848 – 3. The maximum reflectance or exposure from the original scene.

849 – 1. The exact shape of the characteristic curve depends on the spectral quality and intensity of the exposing light, the exposure time, the physical conditions under which the film is stored, exposed, and processed, the chemical composition of the processing solutions, and the instruments used for measuring the densities.

850 – 1. The curve farthest to the left yields a speed twice that of the emulsion to the right.
850 – 2. In the areas of no exposure.
850 – 3. Adjust the exposure of the sensitometer until two steps within the toe are identical in base density readings.

851 – 1. Exposure latitude.
851 – 2. The process and the scene-brightness range.
851 – 3. Color reversal films will, in general, have a shorter exposure latitude than that of color negative materials.
851 – 4. At some point on the toe region of the characteristic curve.

852 – 1. Chemical action, radiation, static electricity, or other forms of radiation.
852 – 2. An increase in overall density.
852 – 3. D_{max} and the base density of the particular emulsion.

716

853 – 1. Contrast.
853 – 2. Gamma.
853 – 3. Gamma (γ).
853 – 4. Average gradient (G).
853 – 5. Range of the average scene, type of film, exposure, the process, and how the end product is to be viewed.

854 – 1. Once the family of curves is plotted, the various characteristics of the emulsion can be determined.
854 – 2. A color shift is introduced.
854 – 3. The film does not incorporate the masking dyes within its layers.
854 – 4. Color correction should begin by drawing a single horizontal line at the density level where neutrality is most desirable and by dropping down to the horizontal axis (log H or relative log H) where the exposures may be determined.
854 – 5. Additive primary.
854 – 6. To correct for minor variations in color balance caused by normal manufacturing variations or by causes beyond manufacturing control.
854 – 7. The densities of the CC filters are measured at the wavelength of maximum absorption.
854 – 8. The toe, the straight line, and the shoulder.
854 – 9. The midtones (densities from 0.60 to 1.40) are normally the primary concern and represent the first area to balance, since most of the information (if properly exposed) would be represented within this range.
854 – 10. True.
854 – 11. The emulsion is considered balanced for use.
854 – 12. The curves are represented as red, blue and green on the graph.
854 – 13. The complementary filter.

855 – 1. Color negative films are developed only once.
855 – 2. The final dye image formed in each emulsion of a color negative tripack will be complementary in color to those of the original scene.
855 – 3. The density increases from left to right along the graph.
855 – 4. The slowest emulsion will be represented by the curve that is plotted farthest to the right on the graph.
855 – 5. The three tricolor curves should coincide as much as possible over their entire length.
855 – 6. Masked color negative material.
855 – 7. True.

856 – 1. The G–12 deep yellow filter.
856 – 2. Extremely hazy conditions.
856 – 3. Short exposure latitude.
856 – 4. The reflectance characteristics of most living vegetation provide the exposing system with much more infrared energy than does the green or red regions of the spectrum.
856 – 5. The infrared film should receive a simulated exposure from the sensitometer that closely parallels the original exposing conditions.
856 – 6. The cyan dye layer.
856 – 7. You must consider the spectral energy distribution of the light source within the infrared region.
856 – 8. The EG and G Mark VI.
856 – 9. Filtration can only decrease the density of dye layers, selectively.
856 – 10. The cyan–2 series.
856 – 11. From 700 to 1350 nm.
856 – 12. The individual lab should have complete control of all film. This applies to the storage, testing, and processing of all film (especially color materials).

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STOP- 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 05 01

SENSITOMETRIC CONTROL FOR BLACK AND WHITE AND COLOR PROCESSES

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (800) Agitation in sensitometric processors is

   a. seldom used.
   b. is used only on certain tests.
   c. critical.
   d. designed to give uneven agitation.

2. (801) To insure uniform processing solutions for sensitometric test strips, you should set aside

   a. controlled test strips.
   b. certified chemicals.
   c. fresh mixes.
   d. chemical batches.

3. (801) In order to insure comparable results with a previous batch of controlled chemistry, you *must*

   a. maintain control charts on the new batches of chemistry.
   b. certify all chemicals using chemical analysis.
   c. cross check each batch of chemistry.
   d. adjust your standards to new chemistry.

4. (802) Which of the following is *not* a physical factor?

   a. Time.
   b. Oxidation.
   c. Temperature.
   d. Agitation.

5. (802) For any new process, you should run a series of test over a sufficiently long period of time to enable you to arrive at a

   a. normal distribution.
   b. standard deviation.
   c. frequency distribution.
   d. sigma deviation.

6. (803) Exposed but unprocessed control-stock film should *not* be stored longer than

   a. 30 days.
   b. 60 days.
   c. 6 months.
   d. 1 year.

7. (803) Because interaction is always present in production processing, which of the following methods is used to help achieve an adequate and reliable process control?

   a. Physical.
   b. Chemical.
   c. Sensitometric.
   d. Statistical.

8. (804) *Most* of the sensitometers in use today are what type?

   a. IA.
   b. IB.
   c. IIA.
   d. IIB.

9. (804) A difference of 30 degrees Fahrenheit in the temperature at the time of exposure can cause how much Log H change in apparent speed of certain films?

   a. 0.07.
   b. 0.14.
   c. 0.21.
   d. 0.28.

10. (805) By using the electronic flash sensitometer when you are examining a film sample, you can determine

a. the emulsion characteristics.
b. the development method used.
c. the effectiveness of the developer.
d. All of the above.

11. (805) The flashtube from the electronic flash sensitometer emits light about the color quality of

a. tungsten.
b. daylight.
c. infrared.
d. x-rays.

12. (805) How many seconds should you allow as a charging time between flashes of the electronic flash sensitometer?

a. 5.
b. 10.
c. 15.
d. 20.

13. (806) The lamps in the Herrnfeld sensitometer when burning at 120 volts are rated at

a. 2850 K.
b. 3200 K.
c. 3400 K.
d. 4000 K.

14. (806) Partial pressure on the test button will cause the Herrnfeld sensitometer to

a. hum.
b. whistle.
c. click.
d. chatter.

15. (807) The TD series of the Quantalog is designed to measure what kind of densities?

a. Transmission.
b. Reflection.
c. Translucent.
d. Refraction.

16. (807) The filters used in the Quantalog TD102 are normally the Wratten Nos. 92, 93, and 94 which are used for density measurements of

a. cyan, magenta, and yellow.
b. cyan, magenta, and red.
c. green, blue, and yellow.
d. red, green, and blue.

17. (807) When using the Quantalog densitometer, how often should you check the working standards?

a. Daily.
b. Weekly.
c. Monthly.
d. Semi-annually.

18. (808) The density value from each step of a standard step tablet should be

a. 0.15.
b. 0.30.
c. 0.45.
d. 0.60.

19. (808) The D Log H curve is a graphic representation of the effects of exposure and development. Any increase in exposure moves the curve

a. up.
b. down.
c. to the right.
d. to the left.

20. (809) The lower portion (or toe) of the curve is the region of

a. constant gradient.
b. decreasing gradient.
c. increasing gradient.
d. reversal gradient.

21. (809) The ratio of the difference between any two densities on the straight-line portion of the curve and the difference between their corresponding long exposures is called

a. contrast.
b. gamma.
c. contrast infinity.
d. gamma infinity.

22. (809) An increase in gamma may be the result of the following except

a. time.
b. temperature.
c. agitation.
d. exposure.

23. (810) What term is used for the distance between the points on the Log H axis that correspond to the limits of the straight-line portions?

a. altitude.
b. latitude.
c. contrast.
d. average gradient.

24. (810) Latitude depends primarily upon the

a. type of emulsion.
b. amount of exposure.
c. degree of development.
d. type of exposing light.

25. (811) The line bounded by a point 0.10 above the base-plus-fog level and another point separated by 2.0 Log H increments along a characteristic curve makes an angle which determines

a. gamma infinity.
b. latitude value.
c. contrast index.
d. emulsion speed.

26. (811) The curve that gives information concerning the contrast characteristics of other parts of the D Log H curve can be determined quickly by the use of a

a. polygraph.
b. template.
c. gamma meter.
d. nomograph.

27. (812) The method variously known as "USAF Maximum Detail" speed or "half gamma" speed is measured where the tangent slope is how much of a measured gamma?

a. 0.10.
b. 0.25.
c. 0.50.
d. 1.00.

28. (812) In military aerial reconnaissance, significant intelligence data is contained in what area of the photograph?

a. Highlights.
b. Halftones.
c. Shadows.
d. Opaque.

29. (813) A masked color negative which is correctly balanced will result in the three color layers being

a. displaced vertically.
b. displaced horizontally.
c. overlapped.
d. partially overlapped.

30. (813) The layer used to establish the speed point in color negative emulsion is

a. yellow layer.
b. blue layer.
c. green layer.
d. cyan layer.

31. (814) Film speed values are

a. relative values.
b. absolute values.
c. approximate values.
d. definite values.

32. (814) An advantage of the ANSI standard PH 2.34-1969 film speed method is that

a. it can be used for both masked and unmasked emulsions.
b. it can be used with the Aerial Exposure Computer.
c. it can be limited to only unmasked emulsions.
d. it must be used with the Aerial Exposure Computer.

33. (815) The densities that are measured on the original negative show the effects of

a. processing only.
b. exposure only.
c. exposure and processing.
d. the optics system.

34. (815) The USAF Exposure Monitoring Control System is designed to correlate

a. printers to processors.
b. exposure to processing.
c. optics to exposure.
d. sensitometers.

35. (816) To minimize errors in the exposure monitoring control system formula, what type of density readings are taken?

a. maximum readings.
b. average readings.
c. minimum readings.
d. random readings.

36. (816) If minute variations from standards occur, what action should be taken?

a. Investigate.
b. Stop production.
c. Take no action.
d. Change exposures.

37. (817) In constructing a time-gamma chart, it is essential that you

a. plot a family of curves.
b. vary the agitation of the developer.
c. vary the temperature of the developer.
d. use more than one developer.

38. (817) How many time-gamma curves should you plot to obtain reliable results?

a. One.
b. Three.
c. Five.
d. Seven.

39. (818) To construct a time-temperature chart, you start with two time-gamma curves plotted from families of curves processed at different

a. times.
b. exposures.
c. developers.
d. temperatures.

40. (818) When plotting time-temperature charts, you plot temperature in regular increments, while time is plotted

a. arithmetically.
b. algebraically.
c. logarithmically.
d. geometrically.

41. (819) Tone reproduction studies deal with quantitative relationships derived

a. photographically.
b. photometrically.
c. photogrammetrically.
d. photocartographically.

42. (819) The effect that flare light has on a camera image is to

a. decrease the amount of luminance.
b. extend the illuminance.
c. increase the luminance.
d. increase the contrast.

43. (820) In the quadrant system, the negative curve does *not* reflect the

a. material used.
b. exposure received.
c. development received.
d. amount of flare.

44. (820) What would the curve in the IV quadrant appear as, if the flare is eliminated and the negatives and positives are equally matched?

a. Straight, 45 degree diagonal line.
b. Straight, horizontal line.
c. Straight, vertical line.
d. Curved line, with normal slope.

725

45. (821) Putting the film through several generations of reproduction can sometimes improve

a. graininess.
b. granularity.
c. resolution.
d. edge sharpness.

46. (822) A procedure for controlling the duplication of already exposed and developed original negatives is a system called

a. tone reproduction.
b. trigradient.
c. photographic.
d. photometric.

47. (822) When preparing trigradient tome controls to determine the sensitometric characteristics of an emulsion, you construct an H & D curve and compute an average gradient between what two densities?

a. 0.30 to 1.80.
b. 0.30 to 2.10.
c. 0.60 to 1.80.
d. 0.60 to 2.10.

48. (822) Laboratories producing large quantities of work generally use an automatic recording densitometer such as the

a. Niagara.
b. Concord.
c. Quantascan.
d. Eltron.

49. (822) Negatives selected at random should have good photographic densities and should ignore what kind of highlights?

a. Diffuse.
b. Translucent.
c. Reflected.
d. Specular.

50. (822) Suppose your delta determination showed a D Max of 2.00 and a D Min of 0.80 and the delta D is 1.20. This is higher than the upper limit of 0.80 to 1.15. It would be necessary to do what to the tonal scale?

a. Expand the tonal scale.
b. Compress the tonal scale.
c. Consult high gradient tone control scale.
d. Consult medium gradient tone control scale.

51. (823) In the multiple block system, answers to tone control problems can be provided when information is given in which quadrants?

a. I and II.
b. I and III.
c. II and III.
d. III and IV.

52. (823) When reproduction beyond the second generation is necessary, you can use a specific set of tones made with the aid of a second generation

a. duplicating wedge.
b. negative wedge.
c. step wedge.
d. calibrated step wedge.

53. (824) Which class of mosaic rapidly produces a relative composite picture?

a. Controlled.
b. Variable.
c. Uncontrolled.
d. Nonvariable.

726

54. (824) To prevent staining, mosaic prints require sufficient

a. exposure.
b. development.
c. agitation.
d. fixation.

55. (825) Which one of the series below does *not* belong to the series of reciprocally varied constant energy exposures?

a. 16 x 1.
b. 8 x 3.
c. 4 x 4.
d. 2 x 8.

56. (826) A 45 degree line on a reciprocity diagram is what kind of a line?

a. Exposure.
b. Log IT.
c. Constant intensity.
d. Constant time.

57. (826) Intensity-scale curves tend to do what to reciprocity failure characteristics?

a. Conceal them.
b. Reveal them.
c. Interpret them.
d. Interpolate them.

58. (827) At high intensities, the Log IT value does what as the temperature decreases?

a. Decreases.
b. Increases.
c. Decreases and then increases.
d. Increases and then decreases.

59. (827) Although there seems to be no reciprocity failure at -186 degrees Centigrade, what does this temperature do to the sensitivity of the film?

a. No change.
b. Increases.
c. Decreases.
d. None of the above.

60. (828) Exposing an emulsion to light of various constant wavelengths show what kind of reciprocity failure?

a. Complicated.
b. Uncomplicated.
c. Displaced.
d. Lateral.

61. (828) Spectral sensitivity of an emulsion is *not* dependent upon

a. exposure intensity.
b. wavelength.
c. exposure time.
d. emulsion temperature.

62. (829) What is more of a problem in color reversal film as far as reciprocity law failure is concerned?

a. Film speed.
b. Contrast.
c. Exposure.
d. Color shift.

63. (829) Over what extended range of exposure does the three layers of color reversal film usually have similar reciprocity failure characteristics?

a. 1/10 to 1/100 second.
b. 1/10 to 1/500 second.
c. 1/10 to 1/1000 second.
d. 1/10 to 1/2000 second.

64. (830) The intermittency effect is *not* dependent upon

a. amount of exposure.
b. intensity of light.
c. temperature of the light.
d. rate of interruption.

65. (830) An intermittent exposure produces what effect in relation to a corresponding continuous exposure?

a. Lesser.
b. Greater.
c. Same.
d. None of the above.

66. (831) A sensitometric evaluation of color materials is based on what kind of exposures?

a. Color patches.
b. Gray-scale.
c. Liquid filters.
d. Fluorescent light.

67. (831) A step wedge should be non-selective and attenuate the light between what wave lengths?

a. 200 and 430.
b. 300 and 650.
c. 350 and 700.
d. 430 and 770.

68. (832) For controlled sensitometric processing of test film, agitation is provided by what method?

a. Circulating the solution.
b. Stirring devices mounted in processing tanks.
c. Sets of oscillating vanes moving past the surface of the film.
d. Combination of the above.

69. (832) The characteristics of a process are based on what kind of evaluations?

a. Sensitometric.
b. Statistical.
c. Geometrical.
d. Logarithmic.

70. (833) When measuring color densities for the total effect of the three superimposed layers, the kind of densities you are measuring are

a. integral.
b. analytical.
c. specular.
d. diffuse.

71. (833) Analytical densities that identify each dye by a single number are called

a. equivalent neutral densities (END).
b. equivalent neutral print densities.
c. analytical spectral densities (ASD).
d. spectral and diffuse densities.

72. (834) Beer's law pertains to light absorption of a colorant in subtractive color materials with respect to

a. wavelength of light.
b. thickness of the medium.
c. thickness of molecule.
d. relative concentrations of molecules in the dye.

73. (835) Spectral deficiencies in a light source can be corrected by

a. adjusting the light output.
b. changing the light source.
c. changing the emulsion.
d. using filters.

74. (836) An example of an IR absorbing filter is a

a. A25 (red) filter.
b. F29 (red) filter.
c. Wratten 92 filter.
d. Dichoric filter.

75. (836) Gelatin filters should be stored in

a. cool, dry, conditions.
b. moist, warm, conditions.
c. cool, moist, conditions.
d. warm, dry, conditions.

76. (837) One of the *best* known means of modifying the spectral characteristics of the light sources in a color densitometer is by the use of a

a. monochrometer.
b. prism.
c. change in color temperature.
d. wedge.

77. (837) Wavelength of the radiation passing through the slit is determined by

a. size of the prism.
b. size of the slit.
c. position of the slit.
d. position of the prism.

78. (838) To reduce the intensity or change the color of the measuring light, we use a

a. prism.
b. diffraction grating.
c. wedge.
d. monochrometer.

79. (838) Wedges effect the measuring light by

a. absorbing it.
b. reflecting it.
c. transmitting it.
d. transmitting and reflecting it.

80. (839) Visual densitometers should *not* be used

a. for very few readings.
b. for extended periods of time.
c. for short periods of time.
d. when you want reasonable quality.

81. (839) What sensing device is used in visual densitometers?

a. The rods.
b. The eye.
c. Photocells.
d. Photomultiplier tubes.

82. (840) Which type of meter has a scale divided into regular increments?

a. Logarithmic.
b. Null.
c. Electronic.
d. Density.

83. (840) An instrument that indicates that the impulses from two light beams are in balance works on the

a. logarithmic principle.
b. Electronic principle.
c. Density principle.
d. Null principle.

84. (841) An instrument that can be equipped with a recording device capable of recording both spectral transmittance and density values as a function of wavelength is the

a. spectrophotometer.
b. densitometer.
c. sensitometer.
d. microdensitometer.

85. (841) The measurement of color densitometers or spectrophotometer is usually a function of

a. wavelength.
b. density.
c. electronic.
d. dyes.

86. (842) The standardized geometrical arrangement of color densitometers is that which measures what kind of transmission density?

a. Specular.
b. Diffuse.
c. Opaque.
d. Translucent.

87. (843) A direct-reading densitometer is usually calibrated by measuring the

a. density reading.
b. alternating signal.
c. output radiation.
d. reference standard.

88. (843) The two types of integral color densitometers may be either

a. direct reading and null.
b. null and visual.
c. direct reading and double diffused.
d. calibration and direct reading.

89. (844) A three filter densitometer is defined as

a. an instrument that is equipped with red, blue, and green filters for color reading.
b. an instrument that is equipped with three readout stations for each color.
c. an instrument that can read both film and paper densities.
d. an instrument that can be switched from diffused to specular readings.

90. (844) Three filter densitometers are widely used in

a. base photo labs.
b. imagery production.
c. most mobile units.
d. public information areas.

91. (845) An analytical densitometer measurement is based on what absorption factor?

a. Dyes.
b. Emulsion.
c. Film.
d. Filter.

92. (845) The analytical densitometer is also used to determine

a. printing densities.
b. colormetric densities.
c. luminous densities.
d. equivalent neutral densities.

93. (846) When evaluating color films, it is important to produce and compute the density of the sample

a. equivalent neutral density.
b. neutral gray density.
c. zero neutral density.
d. base neutral density.

94. (846) When a neutral density equivalent to 0.48 is obtained from the three component dye densities of a color image, it means that

a. predominant color equals 0.24, others combined equals 0.24.
b. the neutral density is actually 144/3.
c. each color equals 0.16.
d. each color is equal to 0.48.

95. (847) When it is necessary to plot a set of color curves from a control strip with no exposure data available, the construction method is

a. modified relative Log H or modified absolute Log H.
b. modified absolute Log H or density vs density.
c. modified density vs density or relative Log H.
d. density vs density or modified relative Log H.

96. (848) When ideal neutral gray exists in both color negative and positive materials, they can be represented by

a. plotting only a single curve.
b. the maximum reflectance from the original scene.
c. dividing the curve into three distant parts.
d. the shadow area of the original scene.

731

97. (848) Which of the following is needed to produce a straight line and minimum density in color positive materials?

a. Increasing the exposure in equal proportions along the sensitometric curve.
b. Decreasing the exposure in equal proportions along the sensitometric curve.
c. Increasing the exposure equally throughout the entire sensitometric curve.
d. Decreasing the exposure equally throughout the entire sensitometric curve.

98. (849) Which of the following factors have little or no effect on the shape of the color characteristic curve?

a. The processing solution.
b. The exposure time.
c. The measuring instrument.
d. The original stepwedge.

99. (849) Which of the following is a major concern for evaluation of color material from the exposure and processing aspect?

a. Base plus fog.
b. Latitude.
c. Contrast.
d. All of the above.

100. (850) An indication that reversal material received an exposure that did *not* equal that needed to obtain a normal exposure when

a. the toe will be shorter and the straight line will move up and to the right.
b. the toe will be longer and the straight line will move down and to the left.
c. the toe will be shorter and the straight line will move down and to the left.
d. the toe will be longer and the straight line will move up and to the right.

101. (851) Which statement *best* describes exposure latitude?

a. The ability of a photographic emulsion to record in various exposures, satisfactory detail in the mid-tone region of the original scene.
b. The ability of a photographic emulsion to record in a single exposure, satisfactory detail in the shadow region of the original scene.
c. The ability of a photographic emulsion to record in various exposures, satisfactory detail in both areas of the original scene.
d. The ability of a photographic emulsion to record in a single exposure, satisfactory detail in both areas of the original scene.

102. (852) In what area of the sensitometric curve is fog determined for masked color negatives?

a. The mask dye layer.
b. The yellow dye layer.
c. The cyan dye layer.
d. The magenta dye layer.

103. (852) How does fog effect color reversal films?

a. Decrease in density and a lower overall contrast.
b. Increase in density and a lower overall contrast.
c. Decrease in density and a higher overall contrast.
d. Increase in density and a higher overall contrast.

104. (853) Which term was adopted to describe the variation of development in color films?

- a. Average scene.
- b. Average gamma.
- c. Average contrast.
- d. Average gradient.

105. (853) When evaluating color materials for contrast, how is the useful D Max and D Min points determined?

- a. They are based on the slope of the straight line points.
- b. Any points used must be specifically identified by the laboratory.
- c. They are located by averaging the curves D Max and D Min densities.
- d. They are taken from the upper and lower points on the straight line.

106. (844) If the tricolor density readings of the sensitometric strip agrees with the visual impressions of the material being used

- a. the tricolor curves should be displaced parallel over as much of their length as possible.
- b. the tricolor curves should coincide over as much of their length as possible.
- c. the tricolor curves should indicate a color shift particularly in the middle-tones.
- d. the tricolor curves should show three dye layers and the product will appear black.

107. (855) Where is the dye image formed in the color negative process?

- a. Color developer.
- b. Bleach.
- c. Fixer.
- d. Reversal developer.

108. (855) If the visual appearance of a color negative is blue, what color filter is added for correction during exposure?

- a. Yellow.
- b. Cyan.
- c. Magenta.
- d. Blue.

109. (856) Which form of radiation is eliminated in the exposure of infrared materials?

- a. Yellow.
- b. Blue.
- c. Green.
- d. Red.

110. (856) When color balancing infrared color films a magenta filter will shift the balance from

- a. yellow to blue.
- b. green to magenta.
- c. blue to yellow.
- d. cyan to red.

END OF EXERCISE

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IMAGERY PRODUCTION SPECIALIST

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Volume 6

STATISTICAL QUALITY CONTROL METHODS

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Preface

IN THIS VOLUME, you are given additional knowledge of tasks essential to the operation of an Imagery Production facility. The information, both theoretical and factual, lends itself to computations involved in determining statistical procedures to control the quality of the products of your imagery facility. Such controls are needed for the successful reproduction, printing, and processing of reconnaissance mission films.

Chapter 1 upgrades your knowledge of statistical methods used to establish quality controls in an imagery production facility. Such controls are needed to assure quality products from which the amount of data can be extracted.

In Chapter 2, you will study how statistical methods and control charts are used to evaluate chemical procedures.

For easy reference, Appendix A, Common Logarithm Tables, is printed as a supplement. Use it as the text directs.

Code numbers appearing on figures are for preparing agency identification only.

To get an *immediate response* to your questions concerning subject matter in this course, call the author at AV 926-4142 between 0800 and 1600 (MT), Monday through Friday. Otherwise, write the author at 3448 SCHSQ/TTMZS, Lowry AFB, CO 30230-5000 to point out technical errors you find in the text, volume review exercises, or course examination. Sending subject matter questions to ECI slows reponse time.

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Acknowledgement

THE US AIR FORCE is indebted to the Literary Executor of the late Sir Ronald A. Fischer, F. R. S., Cambridge, to Dr. Frank Yates, F. R. S., Rothamsted, and to Messrs. Oliver and Boyd, Ltd., Edinburgh, for permission to reprint Tables 1–2 and 1–16 from their book, *Statistical Tables for Biological, Agricultural, and Medical Research*, in the preparation of this volume.

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Statistics for Imagery Production Laboratories

TO MAINTAIN maximum control over the photographic process, you must cope with the infinite number of variables that affect it. To do this with any measure of success, you must make careful observations of the behavior of your process; you must keep meaningful records of your observations; and you must draw logical conclusions from your analysis of the observed data. You can, if your operation is small, examine every item produced and base your control procedures on what you see. But, if your operation is large, you may not have time to inspect every item. In that case, you will have no choice but to take samples and draw conclusions from the information they give you. However, when you work from samples instead of the entire output of your process, you can only make inferences about the items you do not see, and you will need some plan whereby the probability of your correct inferences is high. That plan is "Statistical Quality Control" and is based upon the field of mathematical statistics.

The field of extreme altitude reconnaissance requires that vast amounts of data (in the form of minute photographic images) be processed with an absolutely minimum loss of intelligence information. Because of this, statistical quality control is an essential part of the imagery production control process. In this chapter, we discuss the mathematical concepts that form the basis for the field of statistics and apply these concepts to the control procedures you will use in your very critical photographic operation.

1-1. Statistical Theory and Methodology

Statistics is a reliable system for collecting, organizing, summarizing, presenting, and analyzing data, and drawing inferences and making decisions as a result of such analysis. It has certain limitations and characteristics that will become clear to you as you learn the essentials of the statistical theory. For example: (1) Statistics is probably the most efficient means for handling large masses of numerical data. (2) The statistical method applies only to data that can be reduced to quantitative form. (3) Although the statistical method is objective, it can be influenced by subjective interpretation.. (4) Statistical techniques are universal and can be applied to almost any field. The same general methods apply to fields such as economics, education, sociology, psychology, biology, chemistry, and astronomy and with equal facility to practical production activities such as photography and the manufacture of products. The only real difference lies in the nature of the accumulated data.

To learn how to use this very useful "tool," statistics, in our field, you must start by learning something about the theory of probability.

A01. Specify why known occurrences are subjected to the laws of probability.

Probability. Strangely enough, the highly respected field of probability came into being because some seventeenth century gambler engaged a mathematician to help him figure out the "odds" in various games of chance. Also strange is the fact that it took such a long time for the rest of the people to recognize that virtually every known occurrence is subject to the same laws of probability. But once it was recognized that random events had a tendency to happen within certain flexible regions of occurrence for a predictable percentage of the time, it was also recognized that probability and statistics could be used to make reasonable predictions about almost any set of random events.

Exercises (A01):

1. Why are known occurrences subjected to the laws of probability?

A02. Specify why the probability of events that, if one occurs, it will preclude the occurrence of any others.

Classical, or A Priori, Probability. The meanings of this phrase are derived from its original use, which has reference to the order of propositions in a deductive demonstration, particularly in Euclidean geometry. According to the classic doctrine, such deductive demonstration rests ultimately upon principles that are self-evident. Hence, what can be known *a priori* can be known merely by reasoning from what is self-evident and, therefore, known without any appeal to the particular facts of experience. To this another meaning was added by Kant, who held that a priori knowledge consists of certain "presuppositions" and principles of understanding that are antecendently necessary in order that experience in general should be intelligible.

Since the theory of probability started with games of chance, it may be easier to understand how the classical theories evolved if we examine gambling games as examples. For instance, assume that we have a perfect coin with a "head" on one side and a "tail" on the opposite side. If we toss this coin a number of times, we can logically assume that heads will come up as often as tails. Since there are two sides to the coin, we can reason that the chance of heads occurring is 1 in 2, or 1/2. We can see that if a head comes up, a tail cannot; and if a tail appears, the head cannot come up; thus, these events are said to be mutually exclusive. As a result of this kind of thinking, a classical definition of probability was developed. It is: If an event is mutually exclusive and can occur in equally likely ways and if n_A of these outcomes have an attribute A, then the probability of A can be stated as the fraction n_A/n. To explain this further, let us look at a few examples.

If we have a perfect die (one of a pair of dice), any one of its six numerical faces can come up when it is tossed. There are six mutually exclusive outcomes, since only one face can come up during any one toss. Assuming that the die is fair, the six outcomes are equally likely; that is, we can expect each face to appear with about the same frequency in the long run. If we want to know the probability that a toss will result in an even number, we can apply the formula

n_A/n

where

n_A = the number of even-numbered faces (3)
n = the number of possible outcomes (6)

Three of the six faces will have the attribute of being even, therefore $n_A/n = 3/6$, or 1/2, indicates the probability that an even number will come up in any one toss. Similarly, the probability that a 3 will come up is 1/6. The probability that some number greater than 2 will appear is 4/6, or 2/3.

For another example, suppose you draw a playing card at random from a full deck. What are your chances of drawing a diamond? Since there are 13 diamonds in a deck of 52 cards, the probability is 13/52, or 1/4. The probability of getting a number between the ace and six (inclusive) of any suit is 24/52, or 6/13.

In these examples, the definition is straightforward and uncomplicated. That is because the outcomes are mutually exclusive and are equally likely. These conditions, however, are not always extant. Suppose a person wanted to know the probability of getting two heads in two tosses of a coin. He might reason that since there are three possible combinations, head-head (HH), head-tail (HT), and tail-tail (TT), the probability would be 1/3, but he would be in error. As you undoubtedly know, the middle combination can occur either as head-tail (HT), or tail-head (TH), depending upon whether the head or the tail appears on the first of the two tosses. Thus, there are actually four equally likely outcomes, and the probability is 1/4.

Notice that according to the classical definition, probability is always some number between 0 and 1, inclusive. The ratio n_A/n must always be a proper fraction, since the total number of possible outcomes is always greater than the number of outcomes having a specified attribute. If an event is certain to occur, its probability is 1; if it is certain not to occur, its probability is 0. The probability of getting a 7 on one toss of a die is 0, while the probability of getting a number less than 7 is 1.

The probabilities determined according to the classical definition are called a priori probabilities. That is, when we decide that the probability of getting a head in one toss of a coin is 1/2, we have done so purely by deductive reasoning. We do not even need a coin in order to figure this out. We accept this statement without feeling that proof is necessary. We have had sufficient experience to know that the statement is true. In other words, the truth of the statement was derived by deduction.

We can easily see that there are defects in the a priori approach. For example, what can you do when the number of possible outcomes is infinite? To cite one instance, you might want to know the probability that an integer drawn at random from an infinite number of integers will be an even number. If you limit the number of integers to say, 20, you might unthinkingly assume that 10 of them would be even, and that the probability would therefore be 1/2. But realize that this theoretical situation assumes that the ordering of integers is regular (1, 2, 3, 4, ..., 20), and this assumption you can't afford to make. This is why. Suppose the order of integers in an infinite series is: 1, 3, 2, 5, 7, 4, 9, 11, 6, ...; where you have the first two integers odd, then the first even integer, the second two odd integers, followed by the second even integer, and so forth. The probability of randomly drawing an even integer from such an infinite ordering is 1/3.

Another weakness of the classical definition appears when the data are biased. If a die is "loaded" to favor one of its faces, what is the probability of any one of the other faces coming up? Certainly the appearance of each of the faces is not equally likely. The a priori definition is of no use to you in this case.

We discover still another weakness when we try to find answers for questions such as: What is the probability that a child born in Denver, Colorado, will be a boy? Or what is the probability that a male will die before age 60? Or what is the probability that a printer lamp will burn less than 100 hours? Or what is the probability that a roll of aerial film will have less than seven defects? We have a right to ask questions such as these and to expect to find the answers in the world of probability theory. But since the classical approach to probability cannot help us here, we must find a way to extend our definition so that it covers problems such as those we have just presented. The way that is most widely used includes some consideration of the frequency of occurrence of events.

Exercises (A02):

1. If an event occurs, will it preclude the occurrence of others?

2. What is the probability of drawing the ace of spades from a deck of 52 different cards?

3. What is the probability of throwing a 6 on a single roll of a die?

4. What is the probability of drawing either an ace or a king from a deck of cards in a single draw?

5. When you decide that the probability of getting a tail in one toss of a coin is 1/2, you have done so by what type of reasoning?

6. What is the probability of at least one tail coming up in two tosses of a fair coin?

7. Why is the classical definition of probability called *a priori?*

A03. Cite the meaning and application of frequency, or a posteriori, probability.

Frequency, or A Posteriori, Probability. The kind of reasoning that derives propositions from the observation of facts, or by generalizations from facts arriving at principles, is *a posteriori* demonstration. It designates, or pertains to, what cannot be known except from experience, proved by induction from facts obtained by observation, or by experiment. To help you think properly about the theory of frequency probability, let us look at the results of an actual experiment.

We selected a new coin at random from a roll of similar coins for this experiment. It seemed to be symmetrical and well balanced and therefore not likely to favor one side over the other. According to the classic theory, if we tossed this coin 100 times, we could expect to get 50 heads and 50 tails. Actually, the results were as shown in table 1-1. Notice that the relative frequency of heads in this test tends to be quite stable and very near to 1/2. This should not surprise us since we believed the coin to be symmetrical and, in the long run, it should come up heads as often as tails. We might think, from this, that we could use the relative frequency from table 1-1 as an approximation for the probability that this particular coin will come up heads. Our thinking would be correct. In fact, we could reasonably assume from the coin experiment that there is a number, p, that is the probability of getting a head from any one toss of the coin. Further, if the coin is balanced, we might use the classical definition and say that p is approximately equal to 1/2. But this can only be an approximation since, for this coin, we cannot be absolutely sure that getting heads or tails is equally likely. On the other hand, we could toss the coin a large number of times, use the same recording procedure as shown in table 1-1, and then take the relative frequency of getting a head for the probability, p. The important thing is that we postulate that there is a number, p, that can be defined as the probability of getting a head with the toss of the coin. In this case, it doesn't make much difference which system we use.

TABLE 1-1

RESULTS AFTER 100 TOSSES OF A COIN

233-71

Outcome	Frequency	Observed Relative Frequency	Expected Relative Frequency in the Long Run
Heads	46	0.46	0.50
Tails	54	0.54	0.50
Total	100	1.00	1.00

However, let us suppose that the coin is not symmetrical and we are reasonably sure that getting heads or tails is not equally likely. We can still use a number, p, for the probability of a head appearing, but we cannot use the classical definition. In this case, we must use the frequency approach.

In imagery production laboratories, as in industry, we seldom have an a priori knowledge of probabilities. Almost all of our probabilities are derived empirically, or a posteriori. Can we tell from examining a processing machine how many defects per roll of processed film it will produce? Of course not. All we can do is let the machine run until it has turned out a large quantity of film and then count the number of defects that have been produced. By finding the ratio of defective parts to the whole output, we obtain what is called the fraction defective. Then we can use this fraction defective of past production as an estimate of the probability of a defect being produced by the machine. This empirically determined probability becomes the basis for determining the future fraction defective output of this machine.

We must note here that the machine must be operating in a random manner. That is, you must let it run without interference. If you alter any factor—speed, temperature, etc.—or attempt any sort of control, you will have inserted bias, and the results will be valueless for determining probability. The probability determined for a randomly operating machine can be used for predicting future performance only if the machine continues to operate in a random manner.

The quality of randomness is essential in the application of statistical methods to the control of any operation, or to the evaluation of any continuous situation. You must understand that all things are subject to variability. No matter how careful we are, no matter how precisely our machines perform, the products we turn out will vary, one from the other. It is true that the differences between the individual items may be so slight that they can only be detected by the most critical measuring devices, but the differences do exist. Our concern is whether or not those differences are significant.

Exercises (A03):

1. What is meant by a frequency or a posteriori probability?

2. In an imagery production laboratory, how are almost all of the probabilities derived?

A04. Given the data from a page of random numbers, cite how to take random samples out of a population and specify the relationship between a population and a sample.

Sampling. At this point, you must learn a few terms you will use as long as you work with statistics. Then we can continue with our discussion knowing that the terms we use will have the same meaning to you that they do to everyone else connected with this field.

First, we have the concept of a population. In statistics, a population is a finite or an infinite collection of individual things, objects, or events. A population, also called a universe, has a distinct identity. A population is not a collection of unrelated things. Even though they might have close similarities, the individuals of a population must have in common some property that distinguishes them from those individuals that do not belong.

The term "population" connotes completeness. On the other hand, a sample, defined as a part of a population, has the connotation of incompleteness. Examples of populations are:

- All of the staff sergeants presently assigned to Air Force imagery production labs.
- The 70mm film processed in a particular processing machine.
- The rolls of film from a given emulsion batch.
- Repeated weighing of chemicals for developing solutions.
- Paydays.

In the first three examples, the "individuals" making up the populations are material things (staff sergeants and film); in the next example, the individuals are physical operations; and in the last example, they are very restricted periods of time. The first is an example of a finite population (notice the "all"), and the rest are infinite.

Next, a sample is a portion of a population taken so that we can make intelligent inferences about the whole population. A sample is subject to certain restrictions:

- It must be taken at random.
- It must be large enough to represent the population.
- It must be taken in such a way that every individual has an equal chance of being chosen.

We will cover various ways of taking samples in later portions of this chapter. Examples of samples are:

- Ten staff sergeants presently assigned to Air Force imagery production labs picked at random.
- Four 3-foot lengths of 70mm film processed in a particular processing machine and picked at random.
- Ten rolls of film picked at random from a given emulsion batch.
- Five weights picked at random from repeated weighing of chemicals.

A distribution is a little harder to define. It is a statistical description of how individuals having some distinguishing property occur in, or are distributed through, the population. For examples of distribution, we might consider the shoe size of the staff sergeants, or the deviations in the weight of chemicals, or the defects in the processed film, or the sensitometric properties of the new film, or the rates of salaries on payday.

We take samples to learn something about the distribution of some property of the individuals in a population.

When we are interested in how often a particular property occurs in the population, we measure the frequency distribution of that property in question.

Since randomness is so important to making valid inferences from sample data, we should consider how to take a random sample and how to know when a process is operating in a random manner.

In spite of the fact that randomness is present in virtually every process of nature and in every product of man's machines, taking a truly random sample is hard to do. People tend to favor certain numbers and like to perform tasks at regular intervals. For instance, a person who is asked to pull samples of the product of a continuously operating machine might carefully extract a sample every 15 minutes, or every hour, or twice each day at the same time. Such a practice is not random; it cannot tell you how a random process is operating. Grave errors in judgment can result from ignoring the nature of randomness. If a sample is taken every hour on the hour, and it so happens that the machine produces a defective product at those particular times, you might throw out your entire output, even though perfect products were being produced at all other times. Of course, the opposite could also be true. The machine might be producing faulty parts at all times except at the times when samples are taken. In that case, you would be accepting a lot of bad products. It is safer to base your sampling procedures on a table of random numbers. There are several such tables, including: the Table of 105,000 Random Decimal Digits, prepared by the Interstate Commerce Commission, Bureau of Transport Economics and Statistics, Rand Corporation's A Million Random Digits; and Fisher and Yates Table XXXIII, from the book *Statistical Tables for Biological, Agricultural, and Medical Research*. One page of the 6-page Fisher and Yates table is illustrated in table 1-2.

TABLE 1·2
RANDOM NUMBERS

03 47 43 73 86	36 96 47 36 61	46 98 63 71 62	33 26 16 80 45	60 11 14 10 95
97 74 24 67 62	42 81 14 57 20	42 53 32 37 32	27 07 36 07 51	24 51 79 89 73
16 76 62 27 66	56 50 26 71 07	32 90 79 78 53	13 55 38 58 59	88 97 54 14 10
12 56 85 99 26	96 96 68 27 31	05 03 72 93 15	57 12 10 14 21	88 26 49 81 76
55 59 56 35 64	38 54 82 46 22	31 62 43 09 90	06 18 44 32 53	23 83 01 30 30
16 22 77 94 39	49 54 43 54 82	17 37 93 23 78	87 35 20 96 43	84 26 34 91 64
84 42 17 53 31	57 24 55 06 88	77 04 74 47 67	21 76 33 50 25	83 92 12 06 76
63 01 63 78 59	16 95 55 67 19	98 10 50 71 75	12 86 73 58 07	44 39 52 38 79
33 21 12 34 29	78 64 56 07 82	52 42 07 44 38	15 51 00 13 42	99 66 02 79 54
57 60 86 32 44	09 47 27 96 54	49 17 46 09 62	90 52 84 77 27	08 02 73 43 28
18 18 07 92 46	44 17 16 58 09	79 83 86 19 62	06 76 50 03 10	55 23 64 05 05
26 62 38 97 75	84 16 07 44 99	83 11 46 32 24	20 14 85 88 45	10 93 72 88 71
23 42 40 64 74	82 97 77 77 81	07 45 32 14 08	32 98 94 07 72	93 85 79 10 75
52 36 28 19 95	50 92 26 11 97	00 56 76 31 38	80 22 02 53 53	86 60 42 04 53
37 85 94 35 12	83 39 50 08 30	42 34 07 96 88	54 42 06 87 98	35 85 29 48 39
70 29 17 12 13	40 33 20 38 26	13 89 51 03 74	17 76 37 13 04	07 74 21 19 30
56 62 18 37 35	96 83 50 87 75	97 12 25 93 47	70 33 24 03 54	97 77 46 44 80
99 49 57 22 77	88 42 95 45 72	16 64 36 16 00	04 43 18 66 79	94 77 24 21 90
16 08 15 04 72	33 27 14 34 09	45 59 34 68 49	12 72 07 34 45	99 27 72 95 14
31 16 93 32 43	50 27 89 87 19	20 15 37 00 49	52 85 66 60 44	38 68 88 11 80
68 34 30 13 70	55 74 30 77 40	44 22 78 84 26	04 33 46 09 52	68 07 97 06 57
74 57 25 65 76	59 29 97 68 60	71 91 38 67 54	13 58 18 24 76	15 54 55 95 52
27 42 37 86 53	48 55 90 65 72	96 57 69 36 10	96 46 92 42 45	97 60 49 04 91
00 39 68 29 61	66 37 32 20 30	77 84 57 03 29	10 45 65 04 26	11 04 96 67 24
29 94 98 94 24	68 49 69 10 82	53 75 91 93 30	34 25 20 57 27	40 48 73 51 92
16 90 82 66 59	83 62 64 11 12	67 19 00 71 74	60 47 21 29 68	02 02 37 03 31
11 27 94 75 06	06 09 19 74 66	02 94 37 34 02	76 70 90 30 86	38 45 94 30 38
35 24 10 16 20	33 32 51 26 38	79 78 45 04 91	16 92 53 56 16	02 75 50 95 98
38 23 16 86 38	42 38 97 01 50	87 75 66 81 41	40 01 74 91 62	48 51 84 08 32
31 96 25 91 47	96 44 33 49 13	34 86 82 53 91	00 52 43 48 85	27 55 26 89 62
56 67 40 67 14	64 05 71 95 86	11 05 65 09 68	76 83 20 37 90	57 16 00 11 66
14 90 84 45 11	75 73 88 05 90	52 27 41 14 86	22 98 12 22 08	07 52 74 95 80
68 05 51 18 00	33 96 02 75 19	07 60 62 93 55	59 33 82 43 90	49 37 38 44 59
20 46 78 73 90	97 51 40 14 02	04 02 33 31 08	39 54 16 49 36	47 95 93 13 30
64 19 58 97 79	15 06 15 93 20	01 90 10 75 06	40 78 78 89 62	02 67 74 17 33
05 26 93 70 60	22 35 85 15 13	92 03 51 59 77	59 56 78 06 83	52 91 05 70 74
07 97 10 88 23	09 98 42 99 64	61 71 62 99 15	06 51 29 16 93	58 05 77 09 51
68 71 86 85 85	54 87 66 47 54	73 32 08 11 12	44 95 92 63 16	29 56 24 29 48
26 99 61 65 53	58 37 78 80 70	42 10 50 67 42	32 17 55 85 74	94 44 67 16 94
14 65 52 68 75	87 59 36 22 41	26 78 63 06 55	13 08 27 01 50	15 29 39 39 43
17 53 77 58 71	71 41 61 50 72	12 41 94 96 26	44 95 27 36 99	02 96 74 30 83
90 26 59 21 19	23 52 23 33 12	96 93 02 18 39	07 02 18 36 07	25 99 32 70 23
41 23 52 55 99	31 04 49 69 96	10 47 48 45 88	13 41 43 89 20	97 17 14 49 17
60 20 50 81 69	31 99 73 68 68	35 81 33 03 76	24 30 12 48 60	18 99 10 72 34
91 25 38 05 90	94 58 28 41 36	45 37 59 03 09	90 35 57 29 12	82 62 54 65 60
34 50 57 74 37	98 80 33 00 91	09 77 93 19 82	74 94 80 04 04	45 07 31 66 49
85 22 04 39 43	73 81 53 94 79	33 62 46 86 28	08 31 54 46 31	53 94 13 38 47
09 79 13 77 48	73 82 97 22 21	05 03 27 24 83	72 89 44 05 60	35 80 39 94 88
88 75 80 18 14	22 95 75 42 49	39 32 82 22 49	02 48 07 70 37	16 04 61 67 87
90 96 23 70 00	39 00 03 06 90	55 85 78 38 36	94 37 30 69 32	90 89 00 76 33

This table is reprinted with permission of R. A. Fisher and F. Yates "Statistical Tables for Biological, Agricultural and Medical Research" (Edinburgh: Oliver & Boyd, Ltd.).

There are many ways to use a table of random numbers. The usual method is: (1) to associate the individual members of a population with the numbers in the table, (2) to take a sample from the set of random numbers, and (3) to withdraw the items with the corresponding numbers from the universe. In this way, you can select a truly random sample of any desired size.

For example, suppose you had a stock of 100 rolls of aerial film on a shelf in your storeroom and you wanted to test a sample of 5. Notice that the numbers in table 1–2 are arranged in groups of 2 digits each. If you number the rolls of film from 00 to 99, you can choose a random sample of five rolls simply by taking any five numbers from the table. Suppose you opened the table to the page shown in the table 1–2 and decided that you would select a series of diagonal numbers from upper left to lower right. You closed your eyes and touched the page with your forefinger. If your finger happened to rest on the fourth block down in the third column from the left, you would be directed to take rolls numbered 13, 12, 36, 68, and 49, corresponding to the numbers in the table.

You can do even more to randomize your selection of a sample. You can flip open the table, place a pencil at random on the page, and use the number under the pencil point to indicate a block number. A second chance selection (conducted like the first) can give you a starting place within the block. If you use your ingenuity, you can devise countless ways to use the table. The more different methods you try, the more likely you are to select random samples.

If you cannot number the members of your population, perhaps you can mix them thoroughly so that their position in the container is random. Theoretically, if the individuals in the universe are thoroughly mixed, any group removed will constitute a random sample.

In some cases, the thing you wish to sample becomes stratified (as sometimes happens when portions of a mixture separate into layers or strata). If this occurs, your best approach is to take a random sample from each stratum if the strata cannot be mixed.

In some situations it is impossible to be completely random. For instance, you would never cut into any part of a roll of aerial film in a processing machine just to find a random spot to insert a sensitometric strip. Such strips should be placed only at the head and tail of a given roll (or between the two ends of a required splice). You would most likely do this for every roll, but if your process is stable, you might not. In such cases, sensitometric strips would be inserted between randomly selected rolls, and a table of random numbers would be used to give you a random schedule.

No matter what process you are trying to sample, you must do your best to follow these rules:

a. Use a method of selection that gives every member of the population an equal chance of being selected.

b. Avoid any method that might in any way associate the selection of an individual with the classification of the individual being selected.

If your process is operating in a random manner, then any portion of the output as a whole may be taken as a random sample. Therefore, it is important to know when the process is operating in a random manner. This is not as simple as it seems. We can best describe a random process indirectly by pointing out when a process is not random. Obviously, a process is not random when it is operating in cycles, exhibits bunchiness, or has an upward or downward trend. Sometimes evidence of nonrandomness is readily apparent; but most frequently the nonrandom characteristics are so indistinct that they can only be detected by the application of some statistical test.

There are several types of tests for determining if a process is operating in a random manner. One is to examine runs (movements of data exhibiting little change) in the data. If there is a long run above or below average, it indicates that nonrandom forces are operating. If there is a long upward or downward run, it indicates nonrandomness. If the runs in the data are too few, it is a sign of nonrandomness. Or, if the runs occur in cycles, it is also a sign that the process is nonrandom.

Another test for random operation involves studying the variation in the samples taken from the process. If the process is operating in a random manner, the samples conform to certain statistical patterns. If the samples do not conform to an appropriate pattern, you can assume that the process is not random.

To study process variability, you must adopt some systematic device for recording and evaluating process fluctuations. The principal device used for this purpose is the control chart. Such a chart presents the variation in the samples of the product over a time increment or according to some other assigned order. The control chart shows up runs or extreme variations which indicate nonrandom fluctuations. We will go into the use of control charts in detail later in this chapter.

At this point, you should be warned that hardly any processes operate in a truly random manner. When we speak of a randomly operating process, we are presenting a concept of an ideal situation for the purpose of instruction and discussion. In practice, you must be satisfied to use statistics in such a way that you can hold your process within acceptable limits. The use of control charts will enable you to know when a process is in control or out of control.

Exercises (A04):

1. What is the relationship between a population and a sample?

2. Using table 1-2, demonstrate how to take two random samples of five individuals out of a population of 100 rolls of aerial film.

3. List the requirements of a sample.

1-2. Acceptance Sampling

If you were to make 100 items, you would probably inspect each one. Since your population or universe is complete and small enough to handle, inspection would be feasible. But, suppose that you planned to produce 100,000 items, or suppose that you intended to continue to produce as long as there was a demand. Either your population would be too large to inspect, or it would be infinite. In either case, some means of sampling must be employed to estimate the quality of your product.

A05. List the requirements of a good sample and, concerning the basis for selecting a sampling plan, state what determines a "random sampling."

Requirements of a Good Sample. What are the requirements of a good sample? There are several.

Representative. A sample must be representative of the whole population. That means that it must be so chosen that every item has an equal chance to be selected.

a. Without bias. It must be selected without bias. The selection should not be influenced by personal opinion.

b. Proper size. It must be the proper size. It should not be so large that it would be too costly or time consuming to process nor should it be so small as to be nonrepresentative of the population.

c. Taken at random. It must be taken at random. When an imagery production specialist speaks of a sample, he or she means a random sample. A random selection can be made in several ways—by pulling numbers out of a hat, by spinning a wheel, or by consulting a table of random numbers. Remember that pure chance is all that governs a random selection, and you must be careful not to inject bias into your sampling procedures.

To be of value, the sample must be an accurate representation of the total production; for example, the total length of footage that has been processed, the complete contents of a boxcar of grain, or all the people who have performed the high jump. The sample must faithfully indicate each characteristic of the whole and reflect any change which may occur in the product. To achieve this, the sample must be of the right size. If too small, the sample will fail to reflect accurately the total product characteristics and any changes which may occur. If too large, it will reflect the above, but the continual procurement of an overly large sample would not be economical or would it necessarily be more accurate than a smaller sample. For example, if three or four sensitometric strips were included within a 1,000-foot processing run, the result might be satisfactory for your particular purpose. In this case, it would be foolish to splice in a "sensi" strip at 50-foot intervals. This would not be economical and probably would not be any more accurate.

The second requirement of the sample is that it must be a random sample. It would be well at this point to define what we mean by "random." *Webster* defines "random" as "without aim, rule, direction; haphazard." This definition will suit us well, for this is the only way in which an accurate sample may be taken. Assume that you were operating an imagery production machine and making sensitometric strip dip tests at set intervals of every 1,000 feet of film run. From these strips you were reading the gamma as a check on machine performance. These strips would not be a good evaluation of the overall performance of the machine for the reason that any action occurring periodically probably would not be caught, unless it happened to occur when the dip test was being made. If strips were processed at random, the chances of catching any variation from normal would be much better.

Since the random selection of a sample, the selection of a proper amount for a sample, and the obtaining of a representative sample have been the subject of much study, we shall not try to cover them here. You should be aware of some of the pitfalls to be encountered. One of the most difficult problems is to achieve a state of randomness. This is not possible by just picking numbers as they enter your mind or by using a similar method. With analysis of the results you will find that instead of being random, the numbers will follow a pattern. There are several methods that can be used, but we shall deal with only two of them at this time. One method is to use charts of random numbers which have been evolved from extensive study. Another method is to place numbered slips of paper in a container and draw the slips from the container. In this selection, you must be careful to replace each slip you draw out. Any sampling system depends on the premise that each individual condition (sample) must have an equal chance of being chosen in subsequent samplings. The use to which you put the numbers will, of course, depend on the type of action in which you are involved. If you are making a sensitometric strip dip test in an imagery production processing machine, the random pattern might be the time interval used between dip tests or the amount of footage run between dip tests.

Any sampling plan is based on the premise that you are taking a certain amount of risk that your sample is representative of the product. The size of the sample and the frequency of the sample are factors that directly affect the risk. If the sample size is small and the frequency with which it is taken is low, then you are taking a much greater risk that the sample is not representative of the whole. Suppose, for example, the owner of a grain elevator wants to test a carload of wheat. If he takes a bushel of wheat from the top of the carload and makes a thorough analysis of this bushel, he will still have a poor test. This test would leave too much of the carload of wheat unsampled. A judgment based on this test could not be safely applied to the entire carload. The wheat at the bottom of the car might be infested with insects. The test would not be comprehensive enough. If, instead, the owner fills 50 test tubes with wheat from scattered positions in the carload, he might analyze much less than a bushel of wheat, but he will have a much more comprehensive test of the entire contents of the car. Thus, you should make certain that your sampling is a comprehensive test of the total situation. On a long run of film through an imagery production processing machine, you would make a densitometric dip test at random distance rather than at just the beginning and the end or at 100, 500, or 1,000 foot lengths.

Exercises (A05):

1. List the requirements of a good sample.

2. What governs a ''random sampling''?

A06. State the basis, requirements, and procedures for designing a sampling plan.

Determination of a Sampling Plan. A fundamental question has to be answered in an imagery production facility: What shall you do with a product that has been submitted for your acceptance—take it, reject it, or sort it?

Three procedures are open to you: (1) accept the lot without any inspection; (2) test every item in the lot—i.e., have 100 percent inspection; and (3) examine a number of samples from the lot and use this information as a basis for making decisions. Procedure 1 is not recommended as a general practice. Procedure 2 sometimes *has* to be done, but as a general practice it is costly and does not give the assurance that many people might believe. Procedure 3, sampling inspection, has the advantage of costing less if it can be done to provide adequate protection to the producer and to the consumer.

The two parties involved in the acceptance sampling situation would like to have an inspection procedure that never rejected a good lot or never accepted a bad lot. However, the producer has to accept the possibility that, under a sampling plan, some of his good lots are going to be falsely rejected. The consumer has to accept the fact that he is going to make the mistake of sometimes accepting bad lots because inevitable fluctuations of sampling error will give rise to some wrong answers.

Problems arise in finding a sampling procedure that can differentiate between good lots and bad lots and in determining how much risk there is that the plan will make mistakes in rejecting a good lot or of accepting a bad one.

Let us take a particular plan and apply the ideas to a specific case. Suppose a plan reads as follows: The lot size shall be in the range 101 to 300. For each such lot, take a random sample of 10 pieces from the lot and inspect each piece in accordance with written instructions to determine whether or not each piece is acceptable or not acceptable. If no more than 2 defective pieces have been found by the time all 10 pieces have been inspected, accept the lot; otherwise, reject it.

What can you expect from this plan? In the *first* place, note that a random sample is required. All sampling plans are based on the assumption that random samples will be taken for inspection. This means that items to be inspected will be taken without bias from as many segments of the lot as cost and handling considerations will permit. It will not do to use the 10 most conveniently available pieces from the lot if we expect the necessary protection promised by the design of the plan.

In the *second* place, note that you are not required to estimate the quality of the lot. All you do is inspect the 10 items in the sample, reject the lot if you find more than 2 defective pieces, and accept it otherwise. It is possible for even a random sample from a good lot to have more than two defective pieces in it and thus be falsely rejected. Likewise it is possible for even a random sample of 10 from a bad lot to have 2 or fewer defectives in it and thus be falsely accepted.

Consider the curve shown in figure 1-1. It is called an operating characteristic or OC curve. The horizontal axis represents various degrees of lot quality in percent defective that may be submitted to the plan for acceptance. The vertical scale is the probability scale. It gives the probability that if a lot of specified percent defective quality is submitted, the plan will accept the lot. Thus, with an OC curve before us, we can see how the plan will react to all kinds of quality from very good to very bad.

To be specific, suppose we define a good lot as one that is 4 percent defective. This is called the acceptable quality level or AQL. The curve tells us that when such a lot is submitted, there is a 95-percent chance that the plan will accept it. What this means is that, out of all of the lots which are 4 percent defective and which are properly inspected by the plan, we can expect about 95 percent of them to be accepted and 5 percent to be rejected. The 5 percent figure is the ''producer's risk,'' because it measures the risk the supplier is willing to take of having a good lot rejected by the plan.

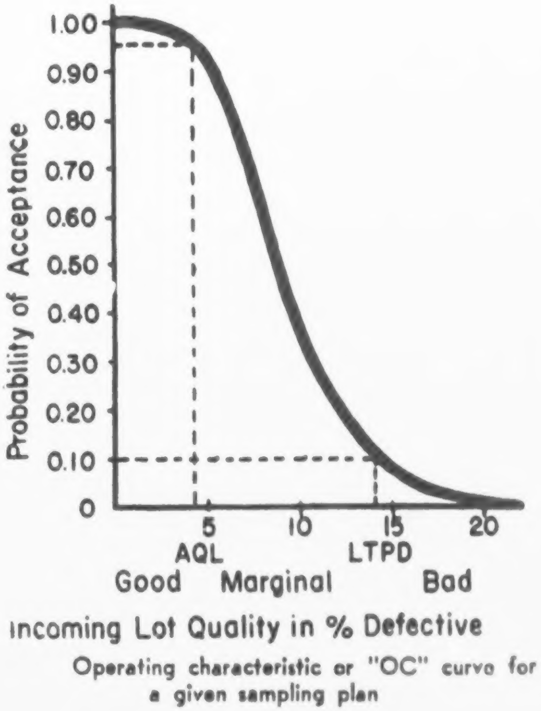


Figure 1-1. Operating curve for a given sample.

At the other end of the scale, let us define a bad lot as one that is 13.6 percent defective. This is called the lot tolerance percent defective or LTPD. The curve tells us that when such a lot is submitted, there is a 10 percent chance that the plan will accept it. Thus, out of all lots that are 13.6 percent defective and which are submitted to this plan, we can expect about 10 percent of them to be accepted. This 10 percent figure is the "consumer's risk," because it measures the risk the user has to run of having a bad lot accepted by this plan.

Whatever value you choose for the AQL or the LTPD, the OC curve for this plan will tell you what you can expect the plan to do to these good and bad lots in the long run. Any AQL and LTPD you choose separates incoming lots into three classes, as shown in figure 1–1. There is: (1) a high possibility of consistently accepting good lots, (2) a low possibility of accepting bad lots, and (3) a decreasing likelihood of taking lots of marginal quality as the submitted lots in this zone get poorer in quality.

The plan we have been discussing is a single sampling plan. There are also double, multiple, and sequential plans available. Usually, you can find, among the battery of plans published in existing tables, one or more that will meet your particular need.

There also exists a battery of scientific sampling plans that can be consulted for an appropriate plan when the inspection test involves the *measurement* of some characteristics rather than simply classifying items as good or bad. These are known as "variables sampling plans." Each such plan also has its own OC curve, and all that has been said about the basic concepts of acceptance sampling by *attributes* can apply with equal force to the case of acceptance sampling by *variables*.

We have tried to emphasize the basic fact that adequate protection can be had economically through the use of a scientific sampling plan, despite the fact that sampling always involves risk. Know what risks you can tolerate and seek a sampling plan that will control these risks at costs you can afford. A plan can always be designed that will fit your requirements, and with a properly designed plan, you are not playing havoc with quality protection. Instead, you will be able to predict very closely how the plan will operate for you if it is properly administered.

An instructive way to find out by simple experiment just how a proposed sampling plan can be expected to work is to get a box of white and colored beads and a scoop with holes that these beads will fit easily. Let the white beads represent good pieces and make up a mixture with varying degrees of defectiveness.

For example, you might use 1,032 white beads, 24 blue beads, 48 green beads, and 96 red beads—a total of 1,200 beads in a box. With such a mixture you can experiment with lots that are 2 percent, 4 percent, 6 percent, 8 percent, 10 percent, 12 percent, and 14 percent defective. A scoop with 100 holes in it will provide for a wide variety of sample sizes. For a given sampling plan, you can then inspect quite rapidly a large number of possible situations and thus verify experimentally that the laws of probability built into modern sampling plans really do work.

Exercises (A06):

1. What is the basis for designing a sampling plan?
2. What do the two parties in an acceptance sampling situation look for in an inspection procedure?
3. In the final analysis, what does the producer accept from a sampling plan?
4. In the final analysis, what does the consumer accept from a sampling plan?
5. What is the purpose of the sampling procedure?

A07. Given data on a frequency distribution, arrange the numbers in an array and find the range.

Frequency Distribution. In statistics, a frequency distribution is a collection of raw, numerical data arranged according to size, or magnitude, and frequency of occurrence.

The first step in calculating a frequency distribution is to accumulate raw data. Raw data are collected data that have not been organized in a numerical ordering. For example, taking the heights of 100 airmen from the alphabetical listing of squadron records would give you a set of unorganized figures. The second step is to set these data down in some sort of array. An array is an arrangement of numerical raw data in an ascending or a descending order of magnitude, as shown in table 1–3. The difference between the largest value and the smallest value is the *range* of the data.

In any analysis of variability, you must distinguish between two types of data: *discrete* data and *continuous* data. Discrete data vary in units. For instance, data obtained from counting are discrete. As an example, suppose you were examining rolls of processed film for defects. You would count the number of defects and tally them. Each defect would be one unit. (You wouldn't have 1½ defects, or 1.75 defects, unless you were speaking in terms of averages.) For each roll of film, the number of defects is a whole number, and the variations in this number must progress in increments of one (see table 1–4).

Continuous data are data that can assume any value within a certain range. The data in table 1–3 are continuous. Potentially, the heights of airmen can assume any value within their range, but because of the limitations imposed by the measuring device, the data in our example seem to vary in jumps. In table 1–3, measurements are given only to

TABLE 1-3
HEIGHTS OF 100 AIRMEN IN BLANK SQUADRON

233-76

Height (inches)	Number of Airmen
60–62	5
63–65	18
66–68	42
69–71	27
72–74	8
	Total 100

the closest inch, but you can see that the data could be given in infinitely small fractions of an inch if a more critical measuring device were used.

Exercises (A07):

1. Arrange the numbers 16, 27, 36, 24, 18, 30, 33, 22, 40, 38, 48, and 49 in an array and find the range.

A08. Given data on a frequency distribution, construct: (a) a frequency distribution, (b) a histogram, and (c) a frequency polygon; and determine an appropriate set of: (a) class intervals, (b) class boundaries, and (c) cell midpoints that might be used informing a frequency distribution.

Construction of Frequency Distributions. Probably the first step, after you have collected your raw data and organized them into a comprehensive array, is to count the number of times a given variation occurs. If you write down the diverse values of a variable in order of size and then tally the frequency with which each size occurs, you will have created a "frequency distrubution." If you do this for an entire population, you will have constructed a frequency distribution for that universe, but you will seldom have time to do this. Besides, for a continuing operation you cannot know what the population is. Therefore, you will be dealing with frequency distributions of samples from which you will make inferences about universes.

Let us take the data from table 1–4, tally them as in figure 1–2, and arrange them as shown in table 1–5. This arrangement shows how often each number of defects has occurred. We see that there were 8 rolls of film in which no defects were found, 12 rolls in which there were 1 defect, 2 rolls in which there were 3 defects, and so forth. The number of defects is a discrete variable; therefore, this distribution is called a discrete frequency distribution.

The frequency distribution can be shown graphically as in figure 1–3. In the figure, the frequencies from table 1–5 are represented by vertical bars. Such a diagram is called a frequency histogram. Notice that in figure 1–3, the bars touch; however, in a discrete distribution, the frequencies apply only to points on the X axis and not to a range of values.

Another graphic representation of a frequency distribution is the frequency polygon shown in figure 1–4. This line graph illustrates the same point values as those shown in figure 1–3, only the points are connected with straight lines.

In making frequency distributions of continuous data, it is almost always necessary to group the data into class intervals. When measurements are fine, very few data occur more than once unless there is an extremely large number of cases. Therefore, to force a frequency of occurrence, it is necessary to establish groups of cells.

When grouping data into classes or cells, you usually adopt an interval of a uniform, constant size. You must decide what size intervals to use and how they are to be located. To do this, you must rely upon your own judgment. If you take too many intervals, the frequency of occurrences will be too few to give you a good distribution.

TABLE 1-4
NUMBER OF DEFECTS IN 30 ROLLS OF PROCESSED FILM

233-77

No. of Roll	No. of Defects	No. of Roll	No. of Defects	No. of Roll	No. of Defects
1	2	11	1	21	1
2	0	12	1	22	1
3	1	13	0	23	2
4	0	14	2	24	2
5	1	15	1	25	1
6	3	16	1	26	0
7	2	17	5	27	0
8	2	18	0	28	0
9	1	19	3	29	1
10	0	20	1	30	4

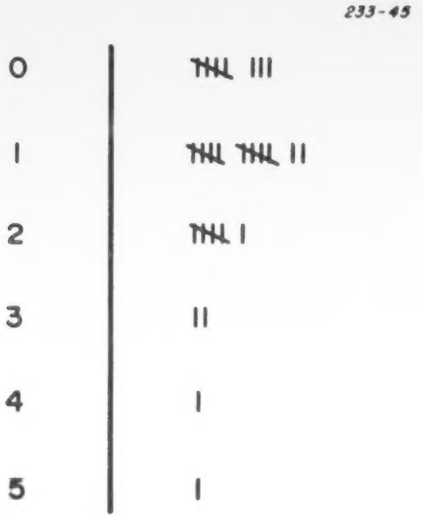


Figure 1–2. Tally sheet to determine frequency distribution from data in table 1–4.

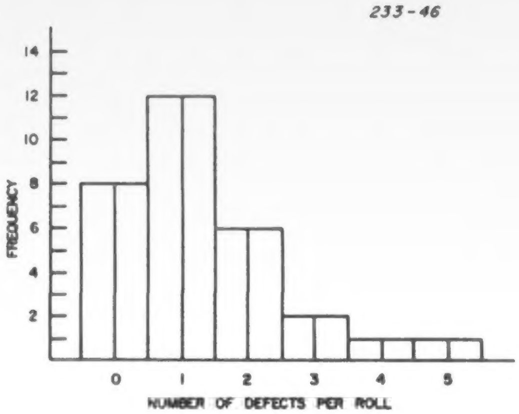


Figure 1–3. Frequency histogram.

On the other hand, if you use too few intervals, your distribution will lack detail. Obviously, you will want some interval that is neither too large nor too small. To learn how to select the correct interval, you must proceed by trial and error. Generally, most distributions contain 10 to 15 intervals but, for purposes of instruction, let us use the intervals indicated for the data in table 1–3.

In table 1–3, the data are grouped into five classes or cells: 60–62, 63–65, 66–68, 69–71, and 72–74. The first cell consists of heights from 60 to 62 inches and is shown by the symbol 60–62. Since five airmen have heights in this class, the class frequency is 5.

The symbol 60–62 is called a class interval or cell interval, and the end numbers, 60 and 62, are called class or cell limits. The smaller number, 60, is called the lower class (or cell) limit, and the larger number, 62, is called the upper class (or cell) limit. Occasionally, a class interval will have no upper or no lower limit. Such a class interval is called an open class interval. An example would be the class interval "65 years and over" when referring to age groups of individuals.

Refer to the data in table 1–3. If the heights were recorded to the nearest inch, the class interval 60–62 would theoretically include all measurements from 59.5000 to 62.5000 inches. These numbers (59.5 and 62.5) are called class boundaries or true class limits. The smaller number is the lower class boundary, and the larger number is the upper class boundary. You can find class boundaries by adding the upper class limit of the lower class interval to the lower class limit of the next higher class interval and dividing by 2.

Class boundaries are sometimes used to symbolize classes. For instance, the classes in table 1–3 could be shown 59.5–62.5, 62.5–65.5, etc. But this could lead to confusion. Suppose you had an actual measurement of 62.5. How could you tell whether it belonged in class interval 59.5–62.5 or in class interval 62.5–65.5? To avoid ambiguity, class boundaries should never coincide with actual measurements.

TABLE 1-5

DISTRIBUTION OF NUMBER OF DEFECTS IN 30 ROLLS OF PROCESSED FILM

233-78

No. of Defects	Rolls with designated No. of Defects	
	No.	Fraction
0	8	0.2669
1	12	0.4000
2	6	0.2000
3	2	0.0665
4	1	0.0333
5	1	0.0333
Totals	30	1.000

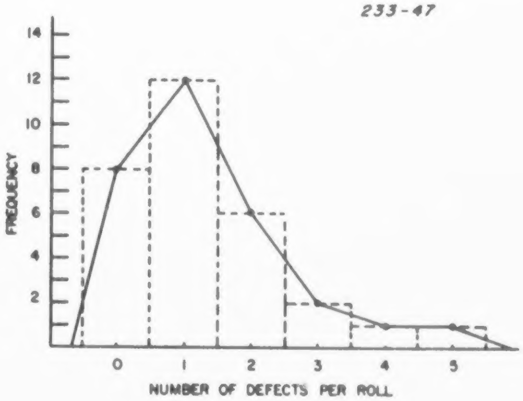


Figure 1–4. Frequency polygon.

233-48

58	0
61	5
64	18
67	42
70	27
73	8
76	0

Figure 1–5. Tally sheet to determine frequency distribution from data in table 1–3.

The class width, also called class size or class length, is defined as the difference between the upper and lower class boundaries. If all class intervals of a frequency distribution have equal widths, the common width is shown by the symbol c, and c is equal to the difference between two successive upper class limits or two successive lower class limits.

Thus

$$c = 65.5 - 62.5 = 62.5 - 59.5 = 3$$

The class mark, also called the cell midpoint, is the midpoint of the class interval. You can obtain it by adding the lower and upper class limits and dividing by 2. Thus the cell midpoint of 60–62 is $(60 + 62) \div 2 = 61$. In practice, all observations belonging to a given class interval are assumed to coincide with the class mark. All heights in class interval 63–65, for instance, are considered to be 64 inches.

To assist you in constructing frequency distributions, we present the following general rules:

a. Find the smallest and largest numbers in the raw data and subtract the smaller from the larger to determine the range.

b. Divide the range into a convenient number of class intervals. Try to have all of the class intervals the same size, but if this is not feasible, you may use class intervals of different sizes, or open class intervals. Depending on the data, class intervals usually range from 5 to 20 in number. Choose your class intervals so that the class midpoints coincide with actually observed data. This tends to lessen grouping errors that often occur when data lie close to but not coincidental with, cell midpoints. However, remember that class boundaries should not coincide with actually observed data.

c. Use a tally sheet (fig. 1–5) to determine the number of observations falling into each class interval (find the frequencies).

You can construct a frequency histogram for continuous data (fig. 1–6) in the same way that you did for discrete data. The frequency polygon is plotted against the cell midpoints.

Exercises (A08):

1. The final grades of 80 airmen completing a CDC course are shown in the following list. Refer to the list and construct an array against an arrangement of class intervals.

73	79	88	73	60	93	71	59	85	75
93	76	88	62	80	68	82	75	84	68
86	67	73	81	72	63	76	75	85	77
74	53	76	62	78	88	57	73	80	65
75	71	65	76	85	78	97	67	62	79
96	78	89	61	75	85	60	79	83	71
61	65	75	87	74	62	95	78	63	72
60	68	74	69	77	94	75	82	78	66

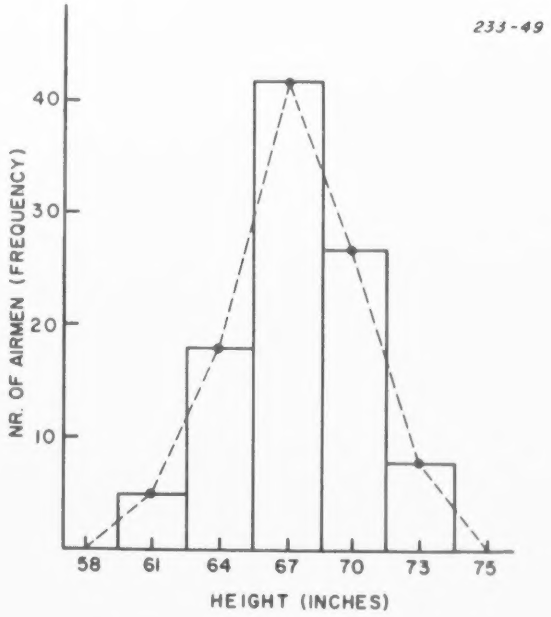


Figure 1–6. Frequency histogram of data in table 1–3.

2. From the data below:
   a. Figure the range of the individual weights, the most convenient class interval, the midpoints, and the class boundaries.

   b. Construct a frequency distribution.

138	146	168	146	161
164	148	126	173	145
150	140	138	142	135
132	147	176	147	142
144	136	163	135	150
125	148	119	153	156
149	152	154	140	145
157	144	165	135	128

3. You have made 150 measurements, the smallest of which is 5.18 cm and the largest is 7.44 cm. Determine an appropriate set of:
   a. Class intervals.

   b. Class boundaries.

   c. Cell midpoints that might be used in forming a frequency distribution.

A09. Given data on a relative frequency distribution, construct: (a) a relative distribution, (b) a relative frequency histogram, and (c) a relative frequency polygon.

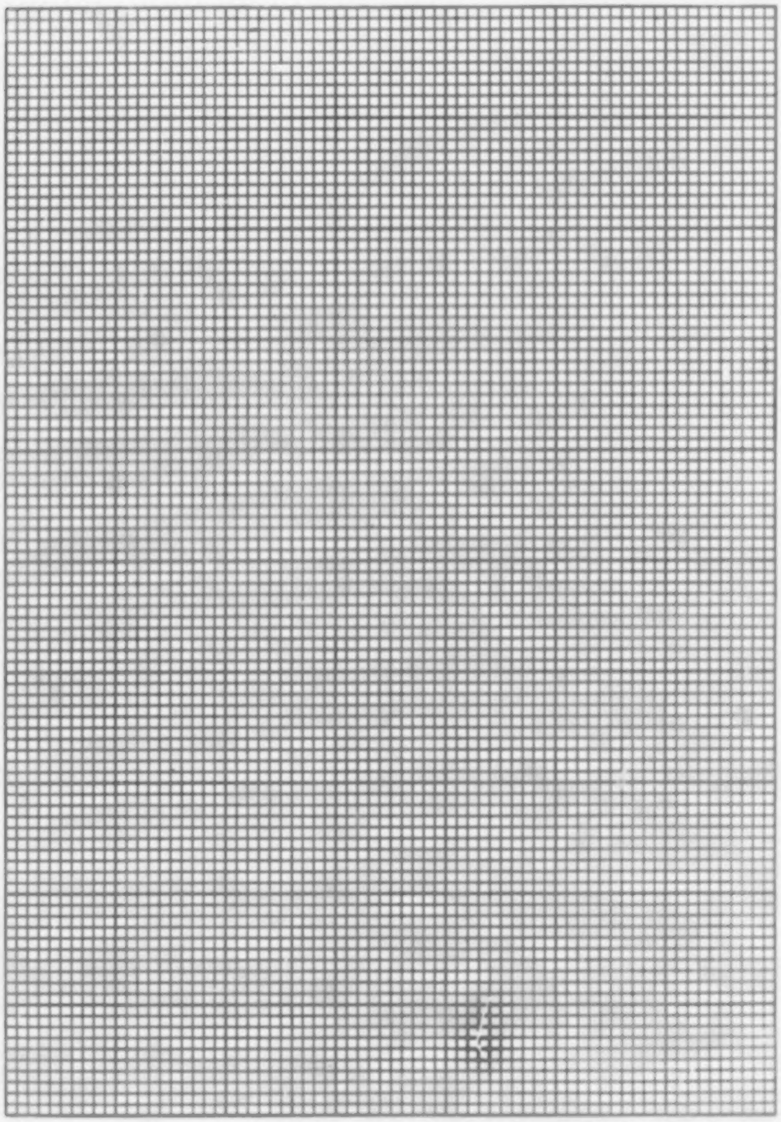
Relative Frequency Distributions. The relative frequency of a given class is the frequency of that class divided by the total frequency of all classes, and it is usually expressed as a percentage. The fraction shown in table 1–5 is the relative frequency of the distribution of the defects in processed roll film. In table 1–3, the relative frequency of the first class interval is 5/100 = 0.05 = 5 percent; for the second class interval, it is 18/100 = 0.18 = 18 percent, etc.

Instead of using frequencies in a frequency table, you can use relative frequencies. When you do this, you call your frequency table a relative frequency distribution, percentage distribution, or relative frequency table.

You can represent relative frequency distributions graphically by using a frequency histogram or a frequency polygon and merely changing the vertical scale from frequency to relative frequency. Otherwise, the diagrams are exactly the same. Such diagrams are called relative frequency histograms or percentage histograms and relative frequency polygons or percentage polygons, respectively.

Exercises (A09):

1. The following is a list of weights, to the nearest point, of 40 airmen assigned to Imagery Production Laboratory. Using the graph paper (fig. 1-7), as appropriate, construct:
   a. A relative or percentage distribution.



233-105

Figure 1-7. Objective A09, exercise 1.

TABLE 1-6

CUMULATIVE FREQUENCY OF HEIGHTS OF 100 AIRMEN

233-79

Height (inches)	Number of Airmen
Less than 59.5	0
Less than 62.5	5
Less than 65.5	23
Less than 68.5	65
Less than 71.5	87
Less than 74.5	100

b. A relative frequency histogram.

c. A relative frequency polygon.

138	146	168	146	161
164	148	126	173	145
150	140	138	142	135
132	147	176	147	142
144	136	163	135	150
125	148	119	153	156
149	152	154	150	145
157	144	165	135	128

A10. Given data on a cumulative frequency distribution, construct: (a) a cumulative frequency distribution, (b) a percentage cumulative frequency distribution, (c) an ogive, and (d) a percentage ogive.

233-50

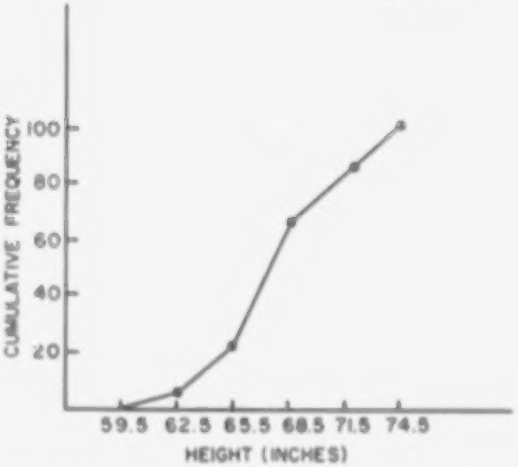


Figure 1-8. Ogive showing cumlative frequency of heights of 100 airmen.

Cumulative Frequency Distributions. Another way of presenting frequency distributions involves cumulating the frequencies from one end or the other, usually from the lower end of the scale to the higher. Stated another way: The total frequency of all of the values less than the upper class boundary of a given class interval is termed the cumulative frequency up to and including that class interval. To illustrate, refer to table 1–3. The cumulative frequency up to and including class interval 63–65 is 5 + 18 = 23. This tells us that 23 airmen are less than 65.5 inches tall. The cumulative frequency up to and including class interval 66–68 is 67, and so forth. A cumulative frequency table of the data from table 1–3 is shown in table 1–6.

You can present cumulative frequencies graphically by plotting the cumulative frequency, less than each upper class boundary, against the corresponding upper class boundary, as shown in figure 1–8. Such a graph is called a cumulative frequency polygon or ogive.

If you wish to show cumulative frequencies as being greater than or equal to the lower class boundary, you may do so by simply reversing the order of procedure described above. Then, because we are talking about heights of 59.5 inches or more, 62.5 inches or more, etc., this is called an "or more" cumulative distribution. By the same reasoning, the first cumulative distribution we discussed is called a "less than" cumulative distribution. Unless an "or more" designation is given, cumulative distributions are always "less than" types.

Exercises (A10):

1. The following is a list of weights, to the nearest point, of 40 airmen assigned to Imagery Production Laboratory. Using the graph paper (fig. 1-9), as appropriate, constuct:
   a. A cumulative frequency distribution.

   b. A percentage cumulative frequency distribution.

   c. An ogive.

   d. A percentage ogive.

138	146	168	146	161
164	148	126	173	145
150	140	138	142	135
132	147	176	147	142
144	136	163	135	150
125	148	119	153	156
149	152	154	140	145
157	144	165	135	128

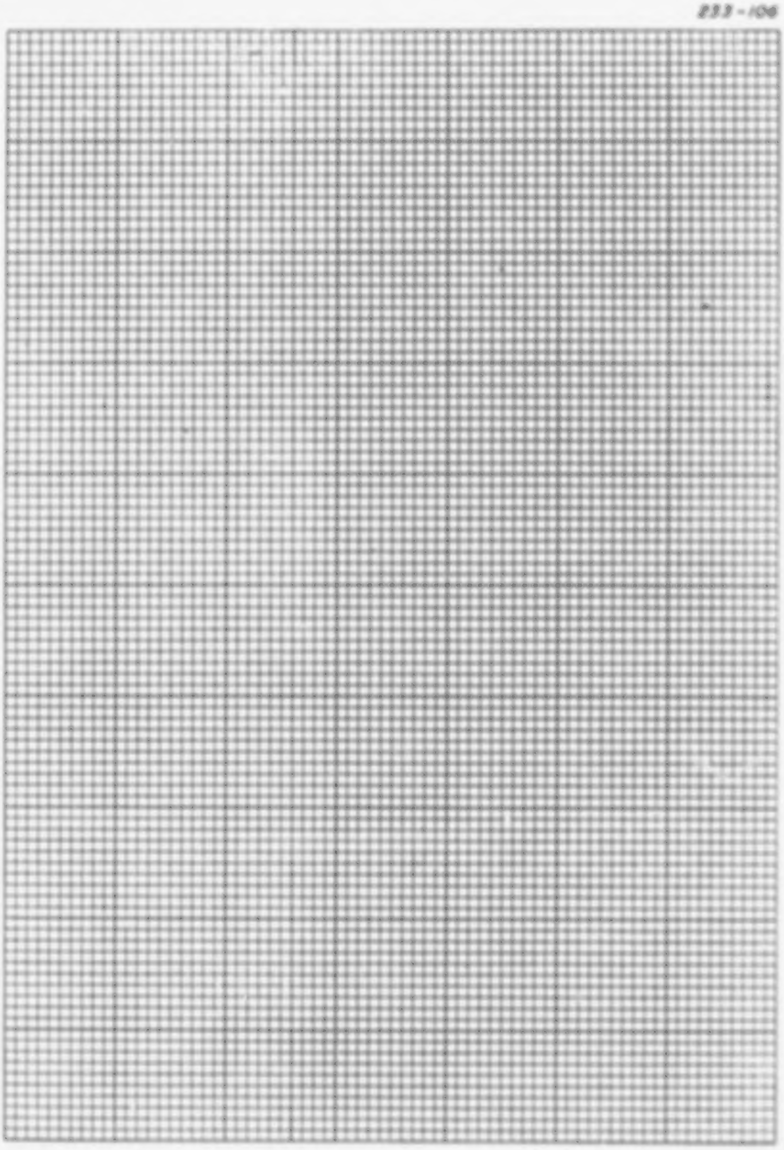


Figure 1-9. Objective A10, exercise 1.

2. From the data in exercise 1, construct:
   a. An "or more" cumulative distribution.

   b. A pe cumulative distribution.

   c. An ogive showing both cumulative and percentage "or more" cumulative frequency. (Use graph paper, fig. 1-10.)

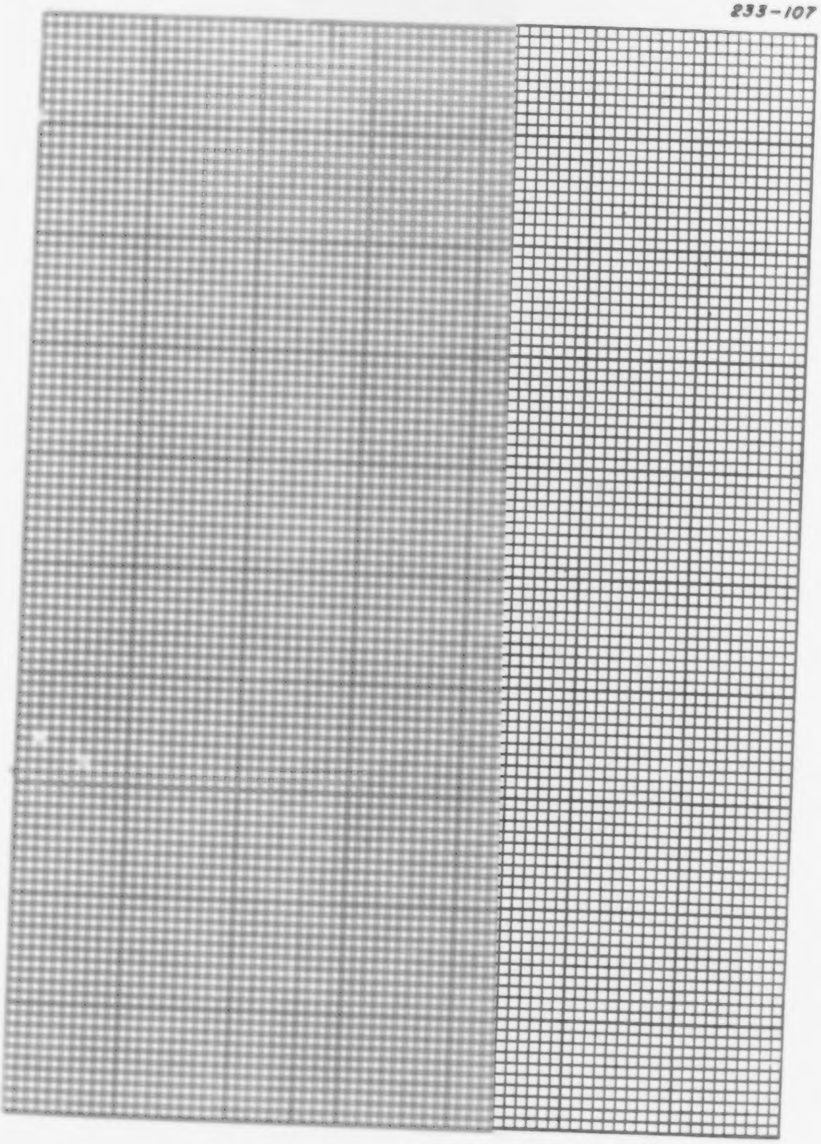

233-107

Figure 1-10. Objective A10, exercise 2.

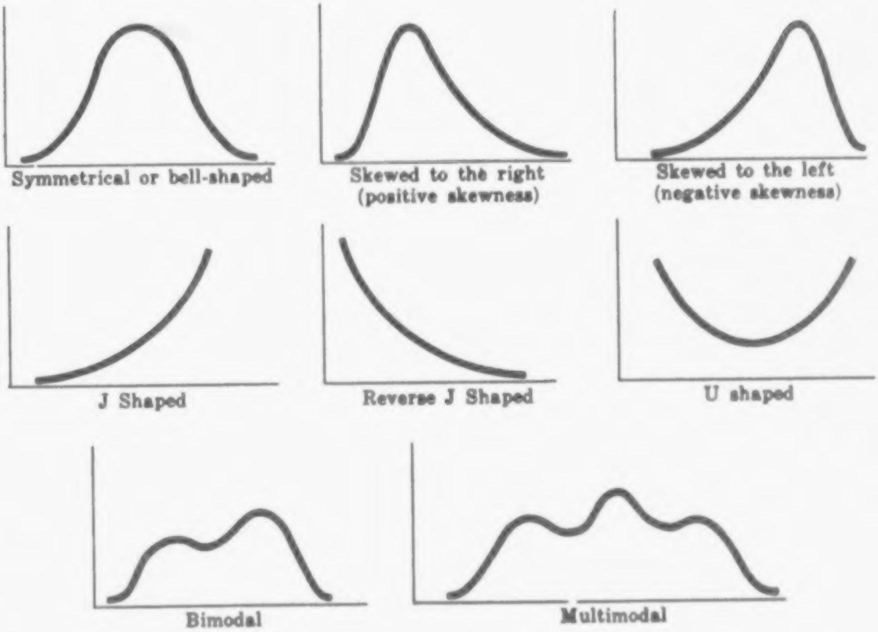

Symmetrical or bell-shaped
Skewed to the right (positive skewness)
Skewed to the left (negative skewness)
J Shaped
Reverse J Shaped
U shaped
Bimodal
Multimodal

Figure 1-11. Characteristic shapes of frequency curves.

A11. List the eight representative shapes of frequency curves and state the characteristic of each curve.

Frequency Curves. When you collect raw data from which you produce frequency distributions, you are, in effect, sampling a large population. Since you have a great many possible observations in a population, it is quite possible to have very small class intervals and still have plenty of observations falling in each class. In such cases, frequency polygons drawn from the data contain so many small broken line segments that they begin to approximate smooth curves. Therefore, you can reasonably expect that you can approximate such theoretical curves by deliberately smoothing the frequency polygon or relative frequency polygons of the sample. Large sample sizes produce the more accurate curves. Frequency curves produced in this manner are sometimes called smoothed frequency polygons.

Smoothing a cumulative frequency polygon produces a smoothed ogive. Smoothed frequency curves and ogives assume several characteristic shapes that can be interpreted to tell you something about the populations from which they were derived. Figure 1-11 illustrates some representative shapes. You should become familiar with these shapes before attempting to analyze them or before trying to make explicit decisions about the populations they represent. Just looking at these curves can give you an intuitive picture of the population, but you will want to depend less on intuition and more on statistical procedures to control a process.

In figure 1-11, the symmetrical or bell-shaped curve is produced because the observations extending equally on either side of a central maximum have the same frequency. This is the shape of the normal or Gaussian curve. The next two figures show moderately asymmetrical, or skewed, curves. Because the longer tail is to the right of the maximum, the curve is skewed to the right, or positively skewed. In the next illustration (fig. 1-11), the longer tail extends to the left, hence the curve is skewed to the left, or negatively skewed. In the J-shaped and reverse J-shaped curves (fig. 1-11), the maximum occurs at one end. When the maximum occurs at both ends, the curve is U-shaped. Because it has two maxima, the curve is called bimodal. If a curve has more than two maxima, it is called multimodal. The curve in the last example (fig. 1-11) has three maxima and can be called either triomodal or multimodal.

Exercises (A11):

1. List the eight representative shapes of frequency curves.

2. State the characteristics of eight representative frequency curves.

1-3. Measures of Central Tendency

Practically all raw data based upon measurements exhibit a distinct tendency to group about one point. You saw examples of this when you studied tallied data for frequency distributions and when you studied the construction of histograms and frequency polygons. The size, shape, and location of the peak or point of common or central tendency thus formed is one of the measurable characteristics that enables us to apply statistics to control procedures in our imagery production laboratories. As a preliminary step to establishing control charts, let us investigate the characteristic called central tendency and learn the various ways of measuring it.

A12. Given data on summation notation, write the terms of the indicated sums and the proper notation.

Notation. To make it easier to discuss the mathematical procedures we are about to undertake, let us adopt some time saving symbols for index or subscript notation and for summation notation. These symbols will serve us for the time being. Others will be added and explained as the need for them arises.

Let the symbol X_j (read "X sub j") denote any of the N values $X_1, X_2, X_3, \ldots, X_N$ assumed by a variable X. The subscript letter j in X_j—which can represent any of the numbers 1, 2, 3, ... N—is also called an index. We must note that any other letters can be, and often are, used in this manner.

The symbol Σ is the Greek capital letter sigma and is used to denote a summation. For example,

$$\sum_{j=1}^{N} X_j$$

denotes the sum of all the X_j's from j = 1 to j = N.

Thus

$$\sum_{J=1}^{N} X_j = X_1 + X_2 + X_3 + \ldots + X_N$$

To save time when there is no chance for confusion, we simply use ΣX, ΣX_j, to $\Sigma_j X_j$. Otherwise, the symbol is used as in the following samples:

$$\sum_{j=1}^{N} X_j Y_j = X_1 Y_1 + X_2 Y_2 + Y_3 Y_3 + X_N Y_N$$

$$\sum_{j=1}^{N} aX_j = aX_1 + aX_2 + \ldots + aX_N = a(X_1 + X_2 + \ldots + X_N) = a \sum_{j=1}^{N} X_j$$

Where a is the constant we can say,

$$\Sigma aX = a \Sigma X$$

If a, b, and c are any constants,

$$\Sigma (aX + bY - cZ) = a \Sigma X + b \Sigma Y - c \Sigma Z$$

Exercises (A12):

1. Write the terms in each of the following indicated sums:

   a. $\sum_{j=1}^{8} X_j$

   b. $\sum_{j=1}^{4} (Y_j - 2)^3$

   c. $\overset{N_a}{\Sigma} j = 1$

   d. $\sum_{k=1}^{6} f_k X_k$

   e. $\sum_{j=1}^{5} X_j - a$

2. Write the proper notation for the following:

   a. $X_1 + X_2 + X_3 + \ldots + X_{20}$

   b. $(X_1 - Y_1) + (X_2 - Y_2) + \cdots + (X_{10} - Y_{10})$

   c. $f_1 X_1{}^2 + f_2 X_2{}^2 + \ldots + f_8 X_8{}^2$

   d. $a_1 b_1 + a_2 b_2 + a_N b_N$

   e. $f_1 X_1 Y_1 + f_2 X_2 Y_2 + \ldots + f_6 X_6 Y_6$

A13. Given data on the arithmetic mean, solve the stated problems.

The Arithmetic Mean. An average is a value that is representative of a set of data. Since such values tend to group in the center of a set of data arranged in order of magnitude, averages are measures of central tendency. The most common type of average is the arithmetic mean, or simply the mean. Other types of averages are the median, the mode, the geometric mean, and the harmonic mean.

The arithmetic mean of a set of N numbers $X_1, X_2, X_3, \ldots, X_N$ is denoted by the symbol $\overline{X}$ (read "X bar").

Thus,

$$\overline{X} = \frac{X_1 + X_2 + X_3, \ldots + X_N}{N} = \frac{\sum_{j=1}^{N}}{N} = \frac{\Sigma X}{N} \qquad (1)$$

For example: To find the arithmetic mean of the numbers 4, 8, 3, 5, 10, 12, proceed as follows:

$$\overline{X} = \frac{4 + 8 + 3 + 5 + 10 + 12}{6} = \frac{42}{6} = 7$$

The arithmetic mean of this set of numbers is 7.

Quite often in statistics, we must average numbers that occur more than once; that is, numbers that have frequency. If the numbers $X_1, X_2, \ldots, X_K$ should occur with frequencies $f_1, f_2, \ldots, f_K$ respectively, the arithmetic mean is stated:

$$\overline{X} = \frac{f_1 X_1 + f_2 X_2 + \ldots + f_K x_K}{f_1 \; f_2 + \ldots + f_K} = \frac{\sum_{j=1}^{K} f_j K_j}{\sum_{j=1}^{K} f_j}$$

$$= \frac{\Sigma fX}{\Sigma f} = \frac{\Sigma fX}{N} \qquad (2)$$

where $N = \Sigma f$ is the total frequency, or total number of cases.

For example, suppose the numbers 4, 7, 3, and 6 occur 5, 2, 4, and 1 times, respectively, the arithmetic mean is:

$$\overline{X} = \frac{(5)(4) + (2)(7) + (4)(3) + (1)(6)}{5 + 2 + 4 + 1}$$

$$= \frac{20 + 14 + 12 + 6}{12} = \frac{52}{12} = 4.33$$

A similar situation occurs when you need to find the mean of weighted values. If the numbers $X_1, X_2, \ldots, X_K$ are weighted $W_1, W_2, \ldots, W_K$, then

$$\overline{X} = \frac{w_1 X_1 + w_2 X_2 + \ldots + w_K X_K}{w_1 + w_2 + \ldots + w_K} = \frac{\Sigma wX}{\Sigma w} \qquad (3)$$

This is called the weighted arithmetic mean.

To illustrate, suppose an airman has just completed a course of instruction during which he took two hourly examinations and one final. If his grades were 80 and 90 on the hourlies and 85 on the final, and if the final was weighted 3 times the hourlies, the weighted mean grade would be:

$$\overline{X} = \frac{(1)(80) + (1)(90) + (3)(85)}{1 + 1 + 3} = \frac{80 + 90 + 255}{5}$$

$$= \frac{425}{5} = 85$$

If you are to have a workable understanding of the arithmetic mean, you should learn some of its properties. In statistics, you are often concerned with deviations from the arithmetic mean of your observed data; therefore, you should note the following.

a. The algebraic sum of the deviations of any set of numbers from their arithmetic mean is zero. As an example, let us take the numbers 8, 15, 7, 4, 12, and 14. The mean is 10. Taking the deviation of each number from the mean gives us the following:

$$\begin{aligned} 8 - 10 &= -2 \\ 15 - 10 &= 5 \\ 7 - 10 &= -3 \\ 4 - 10 &= -6 \\ 12 - 10 &= 2 \\ 14 - 10 &= 4 \end{aligned}$$

The algebraic sum of the deviations is: $-2, +5, -3, -6, +2, +4 = 0$.

b. The sum of the squares of the deviations of a set of numbers, X_j, from any number, a, is a minimum if, and only if, $a = \overline{X}$. That is to say that $\frac{\Sigma(x - a)^2}{N}$ is a minimum if, and only if $a = \overline{X}$.

c. If f_1 numbers have a mean, m_1; f_2 numbers have a mean, m_2 ...; f_K numbers have mean, m_K; then the mean of all the numbers can be shown

$$\overline{X} = \frac{f_1 m_1 + f_2 m_2 + \ldots + f_K m_K}{f_1 + f_2 + \ldots + f_K} \qquad (4)$$

and $\overline{X}$ is a weighted arithmetic mean of all the means.

d. If you guess at, or assume, an arithmetic mean; and if you let A represent the assumed mean; and if you say that $d_j = X_j - A$ represents the deviations of the numbers, X, from the assumed mean A; then equations (1) and (2), respectively, can be stated as follows:

$$\overline{X} = A + \frac{\sum_{j=1}^{N} d_j}{N} = A + \frac{\Sigma d}{N} \qquad (5)$$

$$\overline{X} = A + \frac{\sum_{j=1}^{K} f_j d_j}{\sum_{j=1}^{K} f_j} = A + \frac{\Sigma fd}{N} \qquad (6)$$

Where

$$N = \sum_{j=1}^{K} f_j = \Sigma f$$

This can be summarized in the equation $\overline{X} = A + \overline{d}$, which tells us that the arithmetic mean, $\overline{X}$, of the observed data is equal to the assumed mean, A, plus the mean of the deviations of the observed data from the assumed mean, $\overline{d}$. For a simple illustration, suppose we assume the mean of the set of numbers, 14, 6, 7, 5, 8, to be 6. The deviations of each of these numbers are:

X	d
14	8
6	0
7	1
5	−1
8	2

The algebraic sum of the deviations is 10, and the mean of the deviations is 2. Substituting into the equation

$$\overline{X} = A + \overline{d}$$

we have

$$\overline{X} = 6 + 2 = 8$$

A quick check of the X values will prove that their mean is actually 8. As we have said, this is a simple example given solely to demonstrate the mechanics of applying this formula. In practice, it would never be used for so elementary a problem. It is of value, however, when you desire to compute the arithmetic mean from grouped data.

When data are arranged in a frequency distribution, all values falling within a given cell or class are assumed to have the same value as the cell midpoint. If we call the cell midpoint X_j; the class frequency f_j; a guessed or assumed midpoint A; and the deviations of X, from A, d; then we can apply the formulas (5) or (6). Computations using formula (5) are called the long method, and computations using formula (6) are called the short method.

If the class intervals all have equal size, c; you can express the deviations, $d_j = X_j = A$, as cu_j; where u_j can be positive integers, negative integers, or zero (0, ± 1, ± 2, ± 3 ...,), and formula (1) can then be stated

$$\overline{X} = A + \left(\frac{\sum_{j=1}^{K} f_j u_j}{N} \right) \qquad c = A + \left(\frac{\Sigma f_u}{N} \right) c$$

This is the same as saying X = A + cu. This coding method for computing the mean should always be used for grouped data where the class interval sizes are equal. Note that in this method, the values of the variable, X, are transformed into the values of the variable, u, as $\overline{X} = A + cu$. You will be able to apply this formula while you are working on the problems in the review exercises for this chapter.

Exercises (A13):

1. An airman taking a CDC course consisting of five volumes earned the following grades: 80, 88, 79, 93, and 90. What is the arithmetic mean of his grades?

2. Find the arithmetic mean of the follwing numbers: 5, 4, 6, 2, 5, 5, 7, 8, 7, 4, 7, 6, 9, 8, 5, 3, 5.

3. Using the accompanying frequency distribution of the heights of 100 airmen assigned to Blank Air Force Base, find the mean height of the airmen.

Heights of 100 Airmen Assigned to Blank AFB

Height (inches)	No. of Airmen (Frequency)
60 - 62	5
63 - 65	18
66 - 68	42
69 - 71	27
72 - 74	8
	Total 100

A14. Given two series of numbers, find the median of each.

The Median. The median is the value of the middle item when the items are arranged in order of magnitude. If there are an even number of items in an array, then the median is the arithmetic mean of the two middle items. For examples, consider the following: The median of the set of numbers 1, 2, 2, 3, 4, 4, 5, is 3; the median of the set of numbers 2, 3, 3, 5, 6, 8, 10, 12, 12, 14, 15, 16, is 8 + 10 divided by 2 = 9.

The median differs from the arithmetic mean in that the median is an average of position, while the mean is a calculated average of numerical values.

The median is computed from grouped data by interpolation according to the following formula:

$$\text{Median} = L_1 + \left(\frac{\frac{N}{2} - (\Sigma f)_1}{f_{\text{median}}} \right) c \qquad (7)$$

Where

L_1 = the lower class boundary of the cell containing the median.
N = the number of items in the data (total frequency).
$(\Sigma f)_1$ = the sum of the frequencies in the cells preceding the median cell.
c = the size of the median class interval.

To find the number of the desired median item in your array, divide the total number of items (N) by 2. This gives you the number of the median case. To find the value of the median item, proceed as in the following example.

Let us suppose that a group of 150 airmen took an examination and received grades as shown in the frequency distribution, table 1-7. Since the total number of items is 150, the median item is the 75th item ($\frac{150}{2}$). It occurs in the 10th class interval whose lower class boundary is 70, whose frequency is 18, whose cumulative frequency limits are 61–79, and whose size is 5. Now, applying equation (7):

$$\text{Median} = 70 + \left(\frac{\frac{150}{2} - 61}{18} \right) 5$$

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$$= 70 + \left(\frac{75 - 61}{18}\right) 5$$

$$= 70 + \left(\frac{14}{18}\right) 5$$

$$= 70 + 3.89 = 73.89$$

In this equation, the interpolation is accomplished by the expression

$$\left(\frac{\frac{N}{2} - (\Sigma f)_1}{f_{median}}\right) c$$

Geometrically, the median divides a histogram into two parts having equal areas.

Exercises (A14):

1. You have read and plotted six sensitometric strips developed with six consecutive rolls of film in a processing machine. The gamma values of the strips are as follows: .84, .79, .81, .88, .82. Find the median of the gamma values.

2. Another set of gamma values is as follows: .84, .79, .81, .88, .82, and .80. Find the median of the values.

TABLE 1-7
GRADES OF 150 AIRMEN

233-80

Class Interval No.	Grades (class intervals)	No. of Airmen (frequency)	Cumulative Frequency
1	25 - 29.9	2	2
2	30 - 34.9	4	6
3	35 - 39.9	5	11
4	40 - 44.9	9	20
5	45 - 49.9	8	28
6	50 - 54.9	7	35
7	55 - 59.9	8	43
8	60 - 64.9	4	47
9	65 - 69.9	14	61
10	70 - 74.9	18	79
11	75 - 79.9	24	103
12	80 - 84.9	21	124
13	85 - 89.9	14	138
14	90 - 94.9	7	145
15	95 - 99.9	5	150

A15. Given two sets of numbers, find the mode for each set.

The Mode. The mode of a set of numbers is that value which occurs with the highest frequency. That is, it is the most common value. The set of numbers should be sufficiently large to give a smooth distribution. In others, there may be more than one mode. To illustrate, consider the following examples: In the set of numbers, 2, 3, 3, 4, 7, 7, 7, 9, 9, 11, 13, the number 7 is the mode; in the set 3, 4, 7, 9, 12, 16, there is no mode; and in the set 2, 3, 4, 4, 4, 5, 5, 6, 6, 6, 10, there are two modes, 4 and 6. If there are two modes, the distribution is called bimodal. A distribution having only one mode is called unimodal. A distribution having three modes is called trimodal. Any distribution having several modes may be called multimodal.

If you construct a frequency curve of grouped data, the mode is the value (or values) of X corresponding to the maximum point (or points) on the curve.

You can obtain the mode from a frequency distribution or a histogram by using the formula

$$\text{Mode} = L_1 + \left(\frac{\Delta 1}{\Delta 1 + \Delta 2}\right) c \qquad (8)$$

Where

L_1 = the lower class boundary of the class containing the mode.
1 = the difference between the modal frequency and the frequency of the next lower class.
2 = the difference between the modal frequency and the frequency of the next higher class.
c = the size of the class interval of the modal class.

Exercises (A15):

1. Find the mode for each set of numbers: (a) 3, 5, 4, 5, 4, 5, 3, 6, 2, 7; (b) 42.3, 45.6, 38.9, 44.2, 28.3.

A16. Compare the relationship of mean, median, and mode in a symmetrical and asymmetrical curve.

Relation Between Mean, Median, and Mode. For symmetrical curves, the mean, the median, and the mode all coincide. But for unimodal curves which are asymmetrical (moderately skewed), we have the relationship expressed as follows:

$$\text{Mean} - \text{mode} = 3\,(\text{mean} - \text{median}) \qquad (9)$$

For example, if the average height of 100 airmen was 67.45 inches and the median was 67.06 inches, then

$$\begin{aligned} \text{Mode} &= \text{mean} - 3\,(\text{mean} - \text{median}) \\ &= 67.45 - 3\,(67.45 - 67.06) \\ &= 67.45 - 3\,(.39) \\ &= 67.45 - 1.17 \\ &= 66.28 \text{ inches} \end{aligned}$$

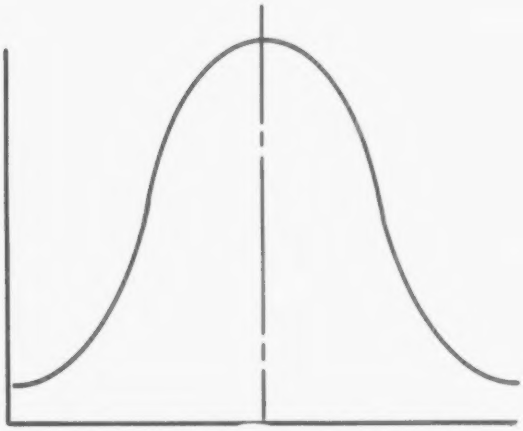


Figure 1–12. Mean, median, and mode are coinidental in symmetrical curves.

Figure 1–12 illustrates the coincidence of the mean, the median, and the mode in a symmetrical curve, while figure 1–13,A, shows their relative positions in a positively skewed curve, and figure 1–13,B, shows their relative positions in a negatively skewed curve.

Exercises (A16):

1. What is the relationship of the mean, median, and mode in a symmetrical curve?

2. State the formula for the relationship of mean, median, and mode in an asymmetrical curve.

A17. Given a set of numbers and a logarithm table, find the geometric mean.

The Geometric Mean, G. The geometric mean of a set of N numbers ($X_1, X_2, X_3, \ldots, X_N$) is the Nth root of the product of the numbers as shown in the following equation:

$$G = \sqrt[n]{X_1\ X_2\ X_3 \ldots X_N} \tag{10}$$

For example, the geometric mean of the set of numbers 8, 4, 2 is

$$G = \sqrt[3]{(8)\ (4)\ (2)} = \sqrt[3]{64} = 4$$

You can compute the geometric mean quite easily if you use a table of logarithms. Otherwise, extracting the Nth root if N is greater than 2 can be virtually impossible.

Exercises (A17):

1. Find the geometric mean of the numbers 3, 5, 6, 6, 7, 10, and 12. Refer to Appendix A.

A18. Given a set of numbers, find the harmonic mean.

The Harmonic Mean, H. The harmonic mean of a set of N numbers ($X_1, X_2, X_3, \ldots, X_N$) is the reciprocal of the arithmetic mean of the reciprocals of the numbers in the set.

Thus,

$$H = \frac{1}{\frac{1}{N}\sum_{j=1}^{N}\frac{1}{X_j}} = \frac{N}{\frac{1}{\Sigma X}} \tag{11}$$

We can state this formula in a simpler form as

$$\frac{1}{H} = \frac{\frac{1}{\Sigma X}}{N} = \frac{1}{N}\ \Sigma\frac{1}{X}$$

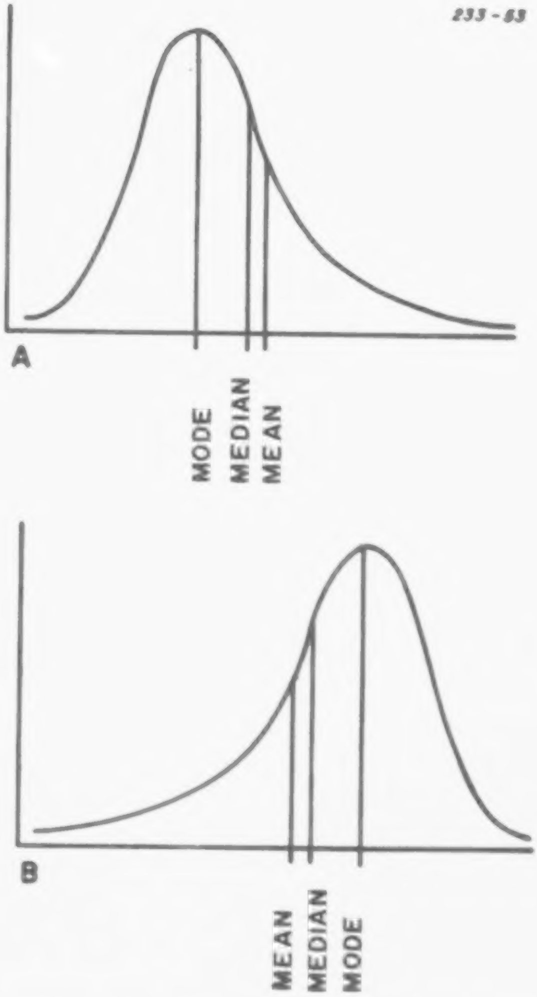


Figure 1–13. Position of the mean, median and mode in skewed curves.

For example: the harmonic mean of the set of numbers 8, 4, 2 is

$$H = \frac{3}{\frac{1}{8} + \frac{1}{4} + \frac{1}{2}} = \frac{3}{.875} = 3.43$$

Exercises (A18):

1. Using 3, 5, 6, 6, 7, 10, and 12, find the harmonic mean.

A19. State the relationship between the arithmetic, geometric, and harmonic means, and from given data solve a problem showing the relationship.

Relationship of Arithmetic, Geometric, and Harmonic Means. The geometric mean of a set of positive numbers ($X_1, X_2, \ldots, X_N$) is less than or equal to their arithmetic mean, and it is greater than or equal to their harmonic mean. This is shown in symbols as

$$H \leq G \leq \overline{X} \qquad (13)$$

The equality sign applies only if the numbers ($X_1, X_2, \ldots, X_N$) are identical.

Exercises (A19):

1. What is the relationship between the arithmetic, geometric, and harmonic means?

2. What are the arithmetic, geometric, and harmonic means for the set 2, 4, and 8?

A20. Given a set of numbers, find the root mean square (RMS).

The Root Mean Square (RMS). In statistics, many evaluations leading to control procedures are based on the root mean square of the observed data. Later in this chapter you will learn how the root mean square is used with frequency distributions. But for now, you will just learn the definition.

The root mean square (RMS), also called the quadratic mean, for a set of numbers $X_1, X_2, \ldots, X_N$ is sometimes expressed $\sqrt{\overline{X^2}}$ and is defined as follows:

$$\text{RMS} = \sqrt{\overline{X^2}} = \sqrt{\frac{\sum_{j=1}^{N} X_j^2}{N}} = \sqrt{\frac{\Sigma X^2}{N}}$$

For example, the root mean square of the set of numbers 1, 2, 5, 8, 10 is

$$\frac{1^2 + 2^2 + 5^2 + 8^2 + 10^2}{5} - \frac{194}{5} = \sqrt{38.8} = 6.23$$

Exercises (A20):

1. Find the root mean square of the set of numbers 3, 5, 6, 6, 7, 10, 12.

A21. Given a table showing data on a frequency distribution, (a) find the quartiles of the distribution and (b) specify the significance of each.

Quartiles, Deciles, and Percentiles. When we separated a set of data arranged in order of magnitude into two equal parts, we identified the value that divided the set as the median. If you divide the identical set of data into four equal parts, the values comprising the divisions are called quartiles and are denoted by the symbols Q_1, Q_2, and Q_3. These values are called the first, second, and third quartiles, respectively, and the value Q_2 is coincidental with the median.

In the same manner, if you divide your data into 10 equal parts, the values that constitute the divisions are called deciles and are denoted by the symbols $D_1, D_2, \ldots, D_9$. The 5th decile coincides with both the median and the second quartile.

The values that divide the data into 100 equal parts are called percentiles and are denoted by the symbols $P_1, P_2, \ldots, P_{99}$. The 50th percentile corresponds to the median, the 5th decile, and the second quartile; and the 25th and 75th percentiles correspond to the first and third quartiles, respectively.

Quartiles, deciles, percentiles, and any other values obtained by dividing data into equal parts are called quantiles.

Exercises (A21):

1. The accompanying table shows a frequency distribution of the grades on a final examination of an Airman Resident Course. (a) Find the quartiles of the distribution. (b) Specify the significance of each.

Grade	No. of Airmen
90 - 100	9
80 - 89	32
70 - 79	43
60 - 69	21
50 - 59	11
40 - 49	3
30 - 39	1
	Total 120

1-4. Measures of Deviation

In the previous sections of this chapter, you learned that events tend not only to occur in a random manner but also tend to occur most frequently about some central point. We wanted you to become interested in the way that observed events are distributed, or scattered, about a midpoint. We also wanted you intuitively to feel that drawing pictures of compiled tables gives you some useful information about the situation that produced the observed events. Now, we feel that you possess the means for learning more about the processes that produced the observed data and the means for learning more about exercising control over the process itself. For the purpose of expanding your knowledge, we will develop additional measurements of the data scattered about the midpoint of frequency distributions.

A22. List the various measures of dispersion or variation.

Dispersion or Variation. The averages, and other measures of central tendency we have covered, do not tell you much about the typical values of the individuals. In fact, averaging tends to conceal individual differences. If you are to learn more about the individual items of observed data, you must employ some quantitative measure of the degree to which these data are scattered. The degree to which numerical data tend to spread out about a mean value is called the dispersion or variation of the data. There are several measurements for dispersion or variation. However, the most common measurements are: range, mean deviation, quartile deviation, and standard deviation. These are the measurements we will discuss here.

Exercises (A22):

1. List the various measures of dispersion or variation.

A23. Given a set of numbers, find the range and compare the dispersion in the set of numbers.

Range. The simplest measure commonly applied to general variability is the range. The range of a set of numbers is the difference between the largest and smallest numbers in the set. For example, the range of the set of numbers 5, 6, 6, 7, 7, 7, 9, 9, 11, 12, is 12 minus 5, or 7. Sometimes the range is indicated by merely giving the first and last numbers of the set. In the example above, the range could be stated as 5 to 12 and written 5–12.

The range applies mainly to discrete, or ungrouped, data. For grouped data, you can take the difference between the upper limit of the highest class interval and the lower limit of the lowest class interval as an estimate of the range, but this is not the usual practice, as you will learn in the following paragraphs.

Exercises (A23):

1. Find the range of each set of numbers:
   a. 6, 12, 3, 7, 15, 18, 10, 5.
   b. 8, 8, 3, 9, 8, 9, 9, 18.
2. How do the dispersions of the sets of numbers in exercise 1 compare with each other?

A24. Given a set of numbers, find the mean deviation.

Mean Deviation. The mean deviation, M.D., or average deviation, A.D., measures the average distance covered by the spread of dispersed items from a central point. The mean deviation of a set of N numbers $X_1, X_2, \ldots, X_N$ is stated as

$$\text{M.D.} = \frac{\sum_{j=1}^{N} |X_j - \bar{X}|}{N} = \left| \frac{\Sigma X - \bar{X}}{N} \right| \qquad (15)$$

Where $\bar{X}$ = the arithmetic mean of the numbers and $|X - \bar{X}|$ is the absolute value of the deviation X_j from $\bar{X}$. (The absolute value of a number is that number with the associated sign omitted.) It is indicated by two vertical lines placed so that one is on either side of the number. Thus $|-5| = 5$, $|+4| = 4$. For example, to find the mean deviation of the set of numbers 2, 4, 6, 8, 10:

$$\bar{X} = \frac{2+4+6+8+10}{5} = 6$$

$$\text{M.D.} = \frac{|2-6| + |4-6| + |6-6| + |8-6| + |10-6|}{5}$$

$$= \frac{|-4| + |-2| + |0| + |2| + |4|}{5}$$

$$= \frac{4+2+0+2+4}{5} = \frac{12}{5} = 2.4$$

If the numbers $X_1, X_2, \ldots, X_K$ occur with frequencies $f_1, f_2, \ldots, f_K$, respectively, the mean deviation can be stated as

$$\text{M.D.} = \frac{\sum_{j=1}^{K} f_j \, |X_j - \bar{X}|}{N} = \frac{|\Sigma f \ | \ X - \bar{X}|}{N}$$

where

$$N = \sum_{j=1}^{K} f_j = \Sigma f$$

This form of the equation should be used for grouped data where the X_j's stand for the class marks (midpoints), and the f_j's represent the corresponding class frequencies.

Sometimes the mean deviation is stated in terms of absolute deviation from the median (or other average) instead of the mean. The sum

$$\sum_{j=1}^{N} \left| X_j - a \right| \tag{16}$$

is a minumum when a is equal to the median; thus, the mean deviation about the median is a minimum.

Exercises (A24):

1. Find the mean deviation of the sets of numbers:

   a. 6, 12, 3, 7, 15, 18, 10, 5.

   b. 8, 8, 3, 9, 8, 9, 9, 18.

A25. Given data, find the quartile deviation.

Quartile Deviation. The quartile deviation, also called the semi-interquartile range, or semiquartile range, Q, is expressed as

$$Q = \frac{Q_3 - Q_1}{2} \tag{17}$$

Where Q_1 and Q_2 are the first and third quartiles for the data.

While the quartile range, $Q_3 - Q_1$, is sometimes used, the semiquartile range, Q, is the range most commonly used.

Exercises (A25):

1. Find the quartile deviation for the height distribution of the airmen as listed in table 1–3.

A26. Given data for a set of numbers, find the standard deviation.

Standard Deviation. When we calculated the mean, or average deviation, we had to ignore the signs. The computed result, while useful for some purposes, is hard to handle in later mathematical developments. For this reason, the standard deviation is commonly used as a measure of variability. Standard deviation is defined as the square root of the average of the squared deviations from the mean. It is generally designated by the symbol σ (the lower case Greek letter sigma) when you are treating the deviations of entire populations, or by the letter s when you are dealing with samples. The calculations for σ or s are basically the same.

The standard deviation of a set of N numbers $X_1, X_2, \ldots, X_N$ is stated as

$$= \sqrt{\frac{\sum_{j=1}^{N} (X_j - \bar{X})^2}{N}} = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N}} = \sqrt{\frac{\Sigma x^2}{N}} \tag{18}$$

where x represents the deviations of each of the numbers, X_j, from the mean, $\bar{X}$.

To calculate the standard deviation of the set of numbers 22.0, 22.5, 22.5, 24.0, 23.5, first find the average of the individuals.

$$\Sigma X = 22.0 + 22.5 + 22.5 + 24.0 + 23.5 = 114.5$$

$$N = 5$$

$$\bar{X} = \frac{\Sigma X}{N} = \frac{114.5}{5} = 22.9$$

Then calculate the deviations of the individuals from the mean.

$$\begin{aligned}
X_5 - \bar{X} &= 23.5 - 22.9 = 0.6 \\
X_4 - \bar{X} &= 24.0 - 22.9 = 1.1 \\
X_3 - \bar{X} &= 22.5 - 22.9 = -0.4 \\
X_2 - \bar{X} &= 22.5 - 22.9 = -0.4 \\
X_1 - \bar{X} &= 22.0 - 22.9 = -0.9
\end{aligned}$$

Next, square the deviations and add the squares.

$$\begin{aligned}
(X_5 - \bar{X})^2 &= (0.6)^2 = 0.36 \\
(X_4 - \bar{X})^2 &= (1.1)^2 = 1.21 \\
(X_3 - \bar{X})^2 &= (-0.4)^2 = 0.16 \\
(X_2 - \bar{X})^2 &= (-0.4)^2 = 0.16 \\
(X_1 - \bar{X})^2 &= (-0.9)^2 = \underline{0.81} \\
\text{Sum of squares } \Sigma X^2 &= 2.70
\end{aligned}$$

Now substitute the appropriate values in the standard deviation formula.

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N}} = \sqrt{\frac{2.70}{5}} = \sqrt{0.54} = .073$$

The standard deviation equation may also be given in the form which follows:

$$\sigma = \sqrt{\frac{X^2_1 + X^2_2 + X^2_3 + \cdots + X^2 n}{N} - \bar{X}^2}$$

$$= \sqrt{\frac{\Sigma X^2}{N} - \bar{X}^2} \tag{19}$$

To illustrate the use of this equation, let us apply it to the set of numbers given above.

$$X^2_5 = 23.5^2 = 552.25$$
$$X^2_4 = 24.0^2 = 576.00$$
$$X^2_3 = 22.5^2 = 506.25$$
$$X^2_2 = 22.5^2 = 506.25$$
$$X^2_2 = 22.0^2 = \underline{484.00}$$

Sum of squares $\Sigma X^2 = 2624.75$

$$N = 5$$

$$\frac{\Sigma X^2}{N} = \frac{2624.75}{5} = 524.95$$

$$\overline{X} = 22.9$$

$$\overline{X}^2 = 22.9^2 = 524.41$$

$$\sigma = \sqrt{\frac{X^2}{N} - \overline{X}^2} = \sqrt{\frac{2624.75}{5} - 524.41}$$

$$\sigma = \sqrt{524.95 - 524.41} = \sqrt{0.54} = 0.73$$

If you have a calculating machine or a comprehensive table of squares, this second equation may be more convenient to use. However, if you do use this equation, you must carry more significant figures in the squares than is necessary in the previous equation.

A third form of the standard deviation equation is

$$\sigma = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma \overline{X})^2}{N}}{N}} \qquad (20)$$

This equation is also used when a large amount of data is being handled.

Equations 18, 19, and 20 describe the treatment for populations. The treatment for samples is:

$$s = \sqrt{\frac{\sum_{i=1}^{N} (X - \overline{X})^2}{n - 1}} = \sqrt{\frac{\Sigma (X - \overline{X})^2}{n - 1}} = \sqrt{\frac{\Sigma x^2}{n - 1}} \qquad (21)$$

Equations (18) and (21) are the same except that the letter s replaces σ, and the quantity $n - 1$, replaces n. (When working with populations, use N for the number of individual observations; when working with samples, use n.) In working with a population, you know that dividing the total value of the cases by the number of individual cases gives you an accurate mean. But, even though samples of a population tend to assume normal distributions, taking their mean can produce only approximate values. It has been found that estimating a population by means of samples (especially when the sample size is small) can be done reliably if you allow a "degree of freedom" in your calculations. The expression $n - 1$ indicates the number of individuals with 1° of freedom and is actually 1 less than the total number of individuals.

While many textbooks use equation (18) for both populations and samples, the Air Force favors the inclusion of equation (21) in its statistical quality control program, inasmuch as the program is extensively involved with samples.

Since σ, or s, is the root mean square of the deviations from the mean, it is sometimes called the root mean square deviation.

You will find that equation (21) is useful when the amount of data is relatively small, but when you must handle large amounts of data, the following formula should be used:

$$s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n - 1}} \qquad (22)$$

In equation (21), you find the deviations of X from $\overline{X}$. You then square each deviation and sum the squared deviations to get the numerator of the fraction under the radical. In equation (22), you square each individual X. Then you sum them. Finally, you subtract the value produced by $\frac{(\Sigma X)^2}{N}$. This value is obtained by: (1) summing the X's, (2) squaring the sum, and (3) dividing by the number of x's (n).

The previous formulas are used when you are working with discrete, ungrouped data. But when you calculate the standard deviation of grouped data, use the following formula:

$$s = c.\,i. \sqrt{\frac{\Sigma fd^2 - \frac{(\Sigma fd)^2}{n}}{n - 1}} \qquad (23)$$

Where

c. i. = the class interval size.
f = frequency of occurrence in each class.
d = deviation of each cell from the mean cell.

As an example, suppose that during a series of processing runs in a continuously operating photographic processing laboratory, you accumulated the following gamma readings:

.74,	.79,	.75,	.83,	.80,	.73,	.77,	.89,	.81,	.81,
.85,	.85,	.80,	.76,	.82,	.78,	.88,	.82,	.83,	.81,
.77,	.87,	.83,	.89,	.84,	.81,	.75,	.79,	.80,	.75,
.69,	.80,	.89,	.70,	.68,	.81,	.80,	.86,	.85,	.92,
.89,	.79,	.71,	.73,	.84,	.87,	.82,	.72,	.86,	.87.

If you group your data, you do not need to construct an array. Instead, you select cell intervals and tally the frequency of occurrences within each cell. To determine the proper cell interval size, first find the range of your data by subtracting the lowest value from the highest. Then divide the range by the number of cells you want to work with. In this example, the highest value is 0.92 and the lowest is 0.68. The range, therefore, is 0.92 minus 0.68, or 0.24. Since you are arbitrarily using 9 cells, you divide 0.24 by 9 and get 0.027. You can conveniently round 0.027 off to 0.03. Next, construct a tally as follows:

Cell Interval (c.i.)	Tally
.915 - .945	I
.885 - .915	IIII
.855 - .885	IIIII I
.825 - .855	IIIII III
.795 - .825	IIIII IIIII III
.765 - .795	IIIII I
.735 - .765	IIIII
.705 - .735	IIII
.675 - .705	III

Notice that the cell intervals are shown in order of decreasing magnitude. Now complete a chart showing all of the data needed for your calculation as follows:

Cell Midpoint	Cell Limits	f	d	fd	d^2	fd^2
0.93	0.915 - .945	1	4	4	16	16
.90	.885 - .915	4	3	12	9	36
.87	.855 - .885	6	2	12	4	24
.84	.825 - .855	8	1	8	1	8
.81	.795 - .825	13	0	0	0	0
.78	.765 - .795	6	−1	−6	1	6
.75	.735 - .765	5	−2	−10	4	20
.72	.705 - .735	4	−3	−12	9	36
.69	.675 - .705	3	−4	−12	16	48

$f = 50 \quad \Sigma fd = -4 \quad \Sigma fd^2 = 194$

The frequency (f) is the number of occurrences in each cell. The deviation (d) is measured in units of cells, and it is calculated as positive and negative integers above and below the cell containing the greatest number of occurrences. Regardless of the cell interval size, this amounts to coding the uncoded data by multiplying the square root of the value by c.i. in the formula for s. To calculate frequency deviation (fd), simply multiply each frequency by its corresponding deviation. Next, square all of the deviations (d^2), and then multiply each squared deviation by its corresponding frequency (f) to obtain the frequency deviation squared (fd^2). Finally find n, the sum of the frequencies (Σf); the sum of the frequency deviations (Σfd); and the sum of the frequency deviations squared (Σfd^2); then substitute the values into the equation

$$s = c.i.\sqrt{\frac{\Sigma fd^2 - \frac{(\Sigma fd)^2}{n}}{n-1}}$$

Thus,

$$s = 0.03\sqrt{\frac{194 - \frac{-4^2}{50}}{49}} = .03\sqrt{\frac{194 - \frac{16}{50}}{49}}$$

$$= 0.03\sqrt{\frac{194 - .32}{49}} = 0.03\sqrt{\frac{193.68}{49}}$$

$$= 0.03\sqrt{3.95} = 0.03 \times 1.987 = 0.05962$$

$$s = 0.0596$$

Later, you will see how the standard deviation is associated with the limits for control charts.

Exercises (A26):

1. Find the standard deviation for each set of numbers:

   a. 6, 12, 3, 7, 15, 18, 10, 5.

   b. 8, 8, 3, 9, 8, 9, 9, 18.

A27. Define variance and find the variance of a set of numbers.

Variance. Variance, another measure of dispersion, is defined as the sum of the squares of the deviations from the arithmetic mean divided by the number of observations. It is expressed as

$$\frac{\Sigma(X - \bar{X})^2}{N} \qquad (24)$$

Since $\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N}}$, it follows that $\frac{\Sigma(X - \bar{X})^2}{N} = \sigma^2$. Thus, variance is the same as the standard deviation squared.

Exercises (A27):

1. Define variance.

2. Using exercise 1 of objective A23, find the variance of each set of numbers.

A28. Specify the conditions of positive and negative skewness.

Skewness. In the first section of this chapter, you learned that frequency curves have various characteristic shapes. When a curve departs from symmetry, we say that that curve is skewed. We say that the curve is negatively skewed, or skewed to the left, if the tail extends to the left. The curve is positively skewed, or skewed to the right, if the tail extends to the right.

When a distribution is skewed, the mean tends to lie on the same side of the mode as the longer tail. Since this is true, you can take the difference between the mean and the mode as a measure of the asymmetry of the distribution. Two of the more common definitions of skewness are given by the following equations:

$$\text{Skewness} = \frac{\text{mean} - \text{mode}}{\text{standard deviation}} = \frac{\bar{X} - \text{mode}}{s} \qquad (25)$$

and

$$\text{Skewness} = \frac{3\ (\text{mean} - \text{median})}{\text{standard deviation}} = \frac{3\ (\bar{X} - \text{median})}{s} \qquad (26)$$

Equation (25) is called Pearson's first coefficient of skewness, and (26) is Pearson's second coefficient of skewness.

Exercises (A28):

1. What are the conditions of positive and negative skewness?

A29. Identify the respective variations of kurtosis as demonstrated by (a) a normal distribution, (b) a distribution with a low, flat peak, and (c) a distribution with a high peak.

Kurtosis. Kurtosis is the degree of peakedness of a distribution. If a distribution has higher-than-normal-peak, as illustrated in figure 1-14, (a), it is called leptokurtic. If it has a peak lower than normal and comparatively flat, as illustrated in figure 1-14, (b), it is called playkurtic. A normal distribution like that shown in figure 1-14, (c) is called mesokurtic.

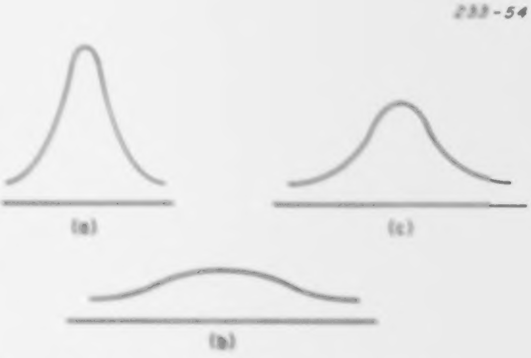


Figure 1-14. Kurtosis: (a) leptokurtic, (b) platykurtic distributions, (c) mesokurtic.

Exercises (A29):

1. What type of kurtosis is shown by (a) a normal distribution, (b) a distribution with a low, flat peak, and (c) a distribution with a high peak?

1-5 Applications of the Probability Theory

To continue our discussion of probability (mentioned at the beginning of this chapter) and to tie probability into statistical quality control, let us state the probability equation in other ways. The classical definition of probability can be considered in the light of (1) the success or (2) the failure of the occurrence of an event. If we designate the success of the occurence of an event as p, and its failure as q, we can make the following statements:

If we assume that an event, E, can happen in h ways out of a total of n possible equally likely ways, then the probability (Pr) of its success is

$$p = \Pr\ (E) = \frac{h}{n}$$

The probability of its failure is

$$q = \Pr\ (\text{not } E) = \frac{n-h}{n} = 1 - \frac{h}{n} = 1 - p = 1 - \Pr\ (E)$$

Therefore, p + q = 1, or Pr (E) + Pr (not E) = 1. The event "not E" may be denoted by using the symbols E, $\tilde{E}$, or -E.

As stated before, the probability of an event will always have some value between 0 and 1, and p = 1 is the measure of certainty, while p = 0 is the measure of impossibility.

If p is the probability that an event will occur, the odds in favor of its happening are p to q (shown as p:q), and the odds against its happening are q:p. For instance, the odds against getting either a 3 or a 4 in a single toss of a fair die are

$$q{:}p = \frac{n-h}{n} : \frac{h}{n} = \frac{6-2}{6} : \frac{2}{6} = \frac{4}{6} : \frac{2}{6} = \frac{2}{3} : \frac{1}{3}$$
$$= 2{:}1, \text{ or } 2 \text{ to} 1$$

If you look critically at the definition of probability, you may feel that the term "equally likely" is rather vague. We could say "equally probable" instead, but then we could be defining probability in terms of itself, and the statement is still just as vague. This is why many people feel that a statistical definition of probability should be used. The empirical or relative frequency probability seems to be a better definition, since the probability itself becomes the limit of the relative frequency as the number of observed occurrences increases indefinitely. For example, if you get 529 heads out of 1,000 tosses of a coin, the relative frequency is 529/1000, or 0.529. If you get 493 heads out of the next 1,000 tosses, the relative frequency becomes (529 + 493) ÷ 2000, or 0.511. According to the definition of statistics, if you continued to toss the coin, you should get closer and closer to a number that could confidently be called the probability of getting a head in a single toss of a coin. From what the 2,000 tosses indicate, that number should be 0.5 (to one significant figure). Further trials and observations might produce additional significant figures.

While this statistical definition has practical value, from a mathematical viewpoint it suffers from the fact that an actual limiting number may not exist at all. For this reason, modern probability theory has been developed axiomatically, entertaining the notion that probability is an undefined concept (just as point and line are undefined in geometry).

A30. Give the term that designates two or more events that cannot possibly occur at the same time.

Mutually Exclusive Events. You recall from our earlier discussion that if two or more events cannot possibly occur at the same time, they are said to be mutually exclusive. If E_1 and E_2 are mutually exclusive events, then $Pr\ (E_1\ E_2) = 0$.

If $E_1 + E_2$ denotes the event that "either E_1 or E_2 or both may occur," then

$$Pr\ (E_1 + E_2) = Pr\ (E_1) + Pr\ (E_2) - Pr\ (E_1 E_2)$$

or

$$Pr\ (E_1 + E_2) = Pr\ (E_1) + Pr\ (E_2)$$

for mutually exclusive events.

To carry this further, if E_1, E_2, ..., E_n are n mutually exclusive events having respective probabilities of occurrence, P_1, P_2, ..., P_n, then the probability of occurrence of either E_1 or E_2 or ... E_n is $P_1 + P_2 \ldots + P_n$.

For example, if E_1 is the event of drawing a king from a complete deck of cards, and E_2 is the probability of drawing a queen, then

$$Pr\ (E_1) = \frac{4}{52} = \frac{1}{13}$$

and

$$Pr\ (E_2) = \frac{4}{52} = \frac{1}{13}$$

The probability of drawing either a king or a queen in a single draw is $Pr\ (E_1 + E_2) = Pr\ (E_1) + Pr\ (E_2) = 1/13 + 1/13 = 2/13$. Since both the king and queen cannot be drawn in a single draw, they are mutually exclusive events.

For another example if E_1 is the event of drawing a deuce of any suit from a deck of cards, and E_2 is the event of drawing any heart, then E_1 and E_2 are not mutually exclusive because the deuce of hearts can be drawn. The probability of drawing either a deuce, a heart, or both is

$$Pr(E_1 + E_2) = Pr\ (E_1) + Pr\ (E_2) - Pr\ (E_1 E_2)$$

$$= \frac{4}{52} + \frac{13}{52} - \frac{1}{52} = \frac{16}{52} = \frac{4}{13}$$

Exercises (A30):

1. In the language of statistics, how do you describe two or more events that cannot possibly occur at the same time?

A31. Define conditional probability, identify dependent and independent events, and show symbolically the probability of compound events.

Conditional Probability. If E_1 and E_2 are two events, the probability that E_2 will occur if E_1 has already occurred is denoted by $Pr\ (E_2|E_1)$ and is called the conditional probability of E_2, given that E_1 has occurred.

If the probability of the occurrence of E_2 is the same regardless of whether E_1 has occurred or not, E_1 or E_2 are said to be independent events.

If the probability that E_2 will occur is in any way affected by the occurrence or nonoccurrence of E_1, the two events are said to be dependent events.

A compound event, where both E_1 and E_2 occur, can be shown as

$$Pr\ (E_1 E_2) = Pr\ (E_1)\ Pr\ (E_2 | E_1)$$

or as

$$Pr\ (E_1 E_2) = Pr\ (E_1)\ Pr\ (E_2)$$

for independent events.

For three events, E_1, E_2, and E_3, we have

$$Pr\ (E_1 E_2 E_3) = Pr\ (E_1)\ Pr\ (E_2 | E_1)\ Pr\ (E_3 | E_1 E_2)$$

That is, the probability of occurrence of E_1, E_2, and E_3 is equal to the probability of E_1, times the probability of E_2, given that E_1 has occurred, times the probability of E_3, given that both E_1 and E_2 have occurred. We can thus show that

$$Pr\ (E_1\ E_2\ E_3) = Pr\ (E_1)\ Pr\ (E_2)\ Pr\ (E_3)$$

for independent events.

Generally speaking, if E_1, E_2, E_3, ..., E_n are n independent events having respective probabilities p_1, p_2, p_3, ..., p_n, then the probability of occurrence of E_1 and E_2 and E_3 and ..., E_n is $p_1 p_2 p_3 \ldots, p_n$.

To see how this works, let E_1 be the occurrence of heads on the third toss of a coin. Let E_2 be the occurrence of heads on the fourth toss. We see that these are independent events. Assuming that the coin is fair, the probability of getting heads on both the third and the fourth tosses is

$$Pr\ (E_1 E_2) = Pr\ (E_1)\ Pr\ (E_2) = \left(\frac{1}{2}\right)\ \left(\frac{1}{2}\right) = \frac{1}{4}$$

If the probability that person A will make master sergeant in 9 years is 0.7 and the probability that person B will make master sergeant in 9 years is 0.6, then the probability that they will both be master sergeants in 9 years is

$$\Pr\ (E_1E_2) = \Pr\ (E_1)\ \Pr\ (E_2) + (0.7)\ (0.6) = 0.42$$

Now let's assume that you have a jar containing two white chips and three red chips. If you say: The event that the first chip drawn will be white is represented by E_1 and the event that the second chip drawn will be white is represented by E_2, and the chips will not be replaced after being drawn; E_1 and E_2 are dependent events.

Here, $\Pr\ (E_1)$, the probability that the first chip drawn will be white is $\frac{2}{3+2}$, or 2/5. The probability that the second chip drawn will be white, if the first chip drawn is white, is $\Pr\ (E_2|E_1)$, or $\frac{1}{3+1} =$ 1/4. Now, the probability that both chips drawn will be white is

$$\Pr\ (E_1E_2) = \Pr\ (E_1)\ \Pr\ (E_2\,|\,E_1) = \left(\frac{2}{5}\right)\ \left(\frac{1}{4}\right) = \frac{2}{20} = \frac{1}{10}$$

Exercises (A31):

1. Define conditional probability.

2. When are E_1 and E_2 considered to be independent events?

3. When are two events called dependent?

4. Show symbolically the probability of occurrence of compound events.

A32. State the essential difference between discrete and continuous probability distributions.

Discrete Probability Distributions. When a variable (X) can take on a discrete set of values ($X_1, X_2, \ldots, X_k$) with respect to probabilities $p_1, p_2, \ldots, p_k$, where $p_1 + p_2 + \ldots + p_k = 1$, we have a discrete probability distribution for X. The function p(X) has the respective values $p_1, p_2, \ldots, p_k$ for $X = X_1, X_2, \ldots, X_k$. This is called the probability function or frequency function of X. Because X can acquire certain values with given probabilities, it is frequently called a discrete random variable. In the field of statistics, a random value is also called a chance variable or stochastic variable.

To illustrate the principle of discrete probability distribution, let us calculate the probability distribution of the sum of the points that can be obtained when a pair of fair dice are rolled. If we let X denote the sum of the points obtained and p(X) the probability of getting any given point, we can construct a table as follows.

X	2	3	4	5	6	7	8	9	10	11	12
p(X)	1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

From the example, you see that the probability of getting a seven is 6/36 = 1/6. Therefore, if we roll the dice 600 times, we would expect to get a seven 100 times.

Notice that this is the same as the relative frequency distribution except that the relative frequencies are replaced by probabilities. Since this is so, we can think of probability distributions as theoretical, or ideal, limiting forms of relative frequency distributions when we make a very large number of observations. Furthermore, we can consider probability distributions as being distributions for populations, while relative frequency distributions are distributions for samples taken from a population.

By plotting p(X) against X, you can represent the probability graphically. Table 1-8 illustrates a probability histogram drawn from the data given above.

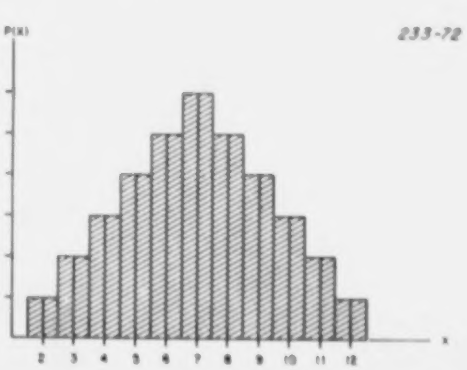
Just as we are able to make cumulative frequency distributions, we can, by cumulating probabilities, obtain a cumulative probability distribution.

Continuous Probability Distributions. In cases where the variable X assumes a continuous set of values, the relative frequency polygon of a sample becomes a continuous curve similar to that shown in figure 1-15. The equation for this curve is $Y = p(X)$. The total area lying under the curve bounded by the X axis is equal to 1. The area under the curve lying between the lines $X = a$ and $X = b$ (the shaded area in the figure) gives the probability that X lies between a and b. This can be shown as $\Pr\ (a < X < b)$.

We refer to p(X) as a probability density function, or simply a density function. When such a function is given, we have defined a continuous probability distribution of X. The variable, X, is called a continuous random variable.

TABLE 1-8

PROBABILITY HISTOGRAM' OF SUMS OF POINTS OBTAINED FROM ROLLS OF A PAIR OF FAIR DICE



Exercises (A32):

1. What is the essential difference between discrete and continuous probability distributions?

A33. Define combinations and permutations, write symbolically a factorial number and solve it mathematically, and solve permutation and combination problems.

Permutations and Combinations. When dealing with complex events, it often becomes difficult and tedious to enumerate all of the cases involved. To make things easier, we employ various systems for calculating the manner in which events occur. Two of these systems involve arrangements, one of which is called permutation and the other is called combination.

To get a general idea about how these arrangements work, let us look at a common situation. If a baseball coach has a squad of 25 men and selects 9 men to form a team, he is, in effect, making a combination of 25 "things" taken 9 at a time. Thus, we see that combinations are groupings of things made regardless of order, while permutations are arrangements of the same things in the sequences of particular orders.

Factorials. Before undertaking further discussion of permutations and combinations, we must assure that you understand factorials. Factorial n, denoted by n!, is defined by the equation

$$n! = n(n-1)\,(n-2)\ldots 1$$

To illustrate:

$$5! = 5\cdot 4\cdot 3\cdot 2\cdot 1 = 120;$$
$$\text{and } 4!\,3! = (4\cdot 3\cdot 2\cdot 1)\,(3\cdot 2\cdot 1) = 144.$$

By definition, $0! = 1$.

Permutations. The three symbols for the total number of all possible permutations of n things, taken r units at a time, are:

$${}_nP_r,\ P(n, r), \text{ or } P_{n,r}$$

You should be able to recognize any of the three symbols when it is given. The equation for the number of permutations of n items taken r units at a time is

$${}_nP_r = n(n-1)\,(n-2)\ldots(n-r+1) = \frac{n!}{(n-r)!}$$

You should recognize that this equation states that the number of permutations of n items taken r units at a time is equal to the factorial of n divided by the factorial of n − r.

In special cases where r = n, that is, when you seek the number of permutations of n things taken n at a time, the equation becomes

$${}_nP_n = n(n-1)\,(n-2)\ldots 1 = n!$$

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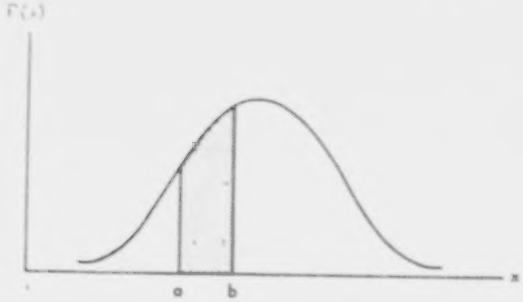

Figure 1-15. Continuous probability curve.

To illustrate, the number of permutations of the letters A, B, C taken two at a time is

$${}_3P_2 = \frac{3!}{(3-2)!} = \frac{3\cdot 2\cdot 1}{1} = 6$$

These are: AB, BA, AC, CA, BC, CB.

The number of permutations of the same letters taken 3 at a time is

$${}_3P_3 = 3! = 3\cdot 2\cdot 1 = 6$$

These are ABC, BAC, CAB, ACB, BCA, and CBA.

The number of permutations of n items consisting of groups of which n_1 are alike and n_2 are alike, ... is given as follows:

$$\frac{n!}{n_1!\,n_2!\ldots}$$

where $n = n_1 + n_2 + \ldots$.

For example, let's consider the number of permutations of the letters in the word "statistics."

$$\frac{n!}{n_1!\,n_2!\ldots} = \frac{10!}{3!\,3!\,1!\,2!\,1!}$$

$$= \frac{10\cdot 9\cdot 8\cdot 7\cdot \overset{2}{\cancel{6}}\cdot 5\cdot \cancel{4}\cdot \cancel{3}\cdot \cancel{2}\cdot 1}{\cancel{3}\cdot \cancel{2}\cdot \cancel{1}\cdot \cancel{3}\cdot \cancel{2}\cdot \cancel{1}\cdot \cancel{1}\cdot \cancel{2}\cdot \cancel{1}\cdot \cancel{1}} = 50{,}400$$

Since the word contains ten letters, the numerator is 10; and since the word contains 3 s's, 3 t's, 1 a, 2 i's, and 1 c, the denominator is 3! 3! 1! 2! 1!.

Notice that our first step in solving the problem was to cancel out all of the factors 1, since they have no effect on the results. Then we cancelled out all possible factors so that all we had to do was to multiply the remaining factors in the numerator. As you become familiar with the factorials, you will drop out the 1's as you set down your problem. If you did this in the equation above, it would be set up as follows.

$$= \frac{10\cdot 9\cdot 8\cdot 7\cdot \overset{2}{\cancel{6}}\cdot 5\cdot \cancel{4}\cdot \cancel{3}\cdot \cancel{2}}{\cancel{3}\cdot \cancel{2}\cdot \cancel{3}\cdot \cancel{2}} = 50{,}400$$

Combinations. The four symbols for the total number of all possible combinations of n items taken r units at a time are

$${}_nC_r;\ C\,(n,\,r);\ Cn,\,r;\ \text{or}\ (r^n)$$

In our work, we will use the symbol ${}_nC_r$ in the equation

$${}_nC_r = \frac{n(n-1)\dots(n-r+1)}{r!} = \frac{n!}{r!\,(n-r)!} = \frac{{}_nP_r}{r!}$$

For example, the number of combinations of the letters ABC taken two at a time is

$${}_3C_2 = \frac{3\cdot 2}{2!\ (3-2)!} = \frac{3\cdot 2}{2} = 3$$

These are AB, AC, and BC. You can see that AB is the same combination as BA, but it is not the same permutation.

If you have the letters A, B, C, and D and wish to find the number of three-letter combinations, we sould solve the problem thus

$${}_4C_3 = \frac{4!}{3!\ (4-3)!} = \frac{4\cdot 3\cdot 2}{3\cdot 2} = 4$$

We would then say that there are four possible combinations. Notice that there are always fewer combinations than permutations. In fact, $c = \frac{1}{r!}\,(P)$ expresses the relationship.

Exercises (A33):

1. Define combinations; permutations.

2. Write 6 factorial symbolically and solve.

3. Show how many permutations of the letters WXYZ can be made if the letters are taken two at a time.

4. How many permutations of the letters in the word "accumulate" are possible?

5. Show symbolically the formula for the total number of all possible combinations of n things taken r at a time.

6. How many combinations of the letters WXYZ taken two at a time can be made?

A34. Given data, apply binomial formula to obtain the coefficients; solve problems on binomial distributions.

Binomial Distributions. Before we get into a discussion of binomial distributions, let us make sure that you understand the binomial theorem and the binomial formula.

The binomial theorem, also called the binomial series, is a rule for expanding the binomial $(a + b)^n$ where n is the positive integer and the binomial formula is given as

$$(a+b)^n = a^n + \left(\frac{n}{1}\right) a^{n-1}b + \frac{n\ (n-1)}{2}\, a^{n-2}b^2 + \dots$$
$$+ \frac{n\ (n-1)}{2}\, a^2b^{n-2} + \left(\frac{n}{1}\right) ab^{n-1} + b^n$$

Or, expanding $(a + b)^n$, the coefficient of a^{n-r} br is $\frac{n!}{(n-r)!r!}$

To explain this, let us expand some binomials by direct multiplication. Take the following examples:

$$(a+b)^2 = a^2 + ab + b^2$$
$$(a+b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$$
$$(a+b)^4 = a^4 + 4a^3b + 6a^2b^2 + 4ab^3 + b^4$$

and verify by multiplication, thus

$$\begin{array}{ccccc}
a & + & b & & \\
a & + & b & & \\
\hline
a^2 & + & ab & & \\
 & & ab & + & b^2 \\
\hline
a^2 & + & 2ab & + & b^2
\end{array}$$

Since

$$(a + b)^3 = (a + b)^2\,(a + b)$$

then

$$\begin{array}{ccccccc}
a^2 & + & 2ab & + & b^2 & & \\
a & + & b & & & & \\
\hline
a^3 & + & 2a^2b & + & ab^2 & & \\
 & & a^2b & + & 2ab^2 & + & b^3 \\
\hline
a^3 & + & 3a^2b & + & 3ab^2 & + & b^3
\end{array}$$

Multiplying the product of $(a + b)^3$ by a + b will give us $(a + b)^4$.

$$\begin{array}{ccccccccc}
a^3 & + & 3a^2b & + & 3ab^2 & + & b^3 & & \\
a & + & b & & & & & & \\
\hline
a^4 & + & 3a^3b & + & 3a^2b^2 & + & ab^3 & & \\
 & & a^3b & + & 3a^2b^2 & + & 3ab^3 & + & b^4 \\
\hline
a^4 & + & 4a^3b & + & 6a^2b^2 & + & 4ab^3 & + & b^4
\end{array}$$

This procedure could be continued indefinitely.

We can take the coefficients only from these products and arrange them in a pattern as follows:

$(a+b)^0$	1
$(a+b)^1$	1 1
$(a+b)^2$	1 2 1
$(a+b)^3$	1 3 3 1
$(a+b)^4$	1 4 6 4 1

In this array, each horizontal line begins and ends with 1. Each of the other entries is the sum of the two numbers on either side of it on the row above it. If we continue in this way, this array, known as Pascal's triangle, can be expanded indefinitely. For example, we could continue expanding the triangle using the two rules stated above and we could get:

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1

By direct multiplication, you can verify that the bottom two rows are $(a+b)^5$ and $(a+b)^6$, respectively.

Generally, whenever there is a pattern like this, there is some formula to describe it. In this case, we can develop a binomial formula that will be much more efficient than the laborious method of direct multiplication.

By definition, the symbol $\binom{n}{r}$, called the binominal coefficient, is

$$\binom{n}{r} = \frac{n!}{(n-r)!\ \ r!}$$

where n and r are integers > 0, and $n > r$.

Now we can write Pascal's Triangle in the form which follows.

$$
\begin{array}{ccccccccccccl}
 & & & & & \binom{0}{0} & & & & & & & (a+b)^0 \\
 & & & & \binom{1}{0} & & \binom{1}{1} & & & & & & (a+b)^1 \\
 & & & \binom{2}{0} & & \binom{2}{1} & & \binom{2}{2} & & & & & (a+b)^2 \\
 & & \binom{3}{0} & & \binom{3}{1} & & \binom{3}{2} & & \binom{3}{3} & & & & (a+b)^3 \\
 & \binom{4}{0} & & \binom{4}{1} & & \binom{4}{2} & & \binom{4}{3} & & \binom{4}{4} & & & (a+b)^4 \\
\binom{5}{0} & & \binom{5}{1} & & \binom{5}{2} & & \binom{5}{3} & & \binom{5}{4} & & \binom{5}{5} & & (a+b)^5
\end{array}
$$

By applying the equation, you can verify that these are the same coefficients that were given earlier. We will start solving for the integers together. After a few examples, you can continue on your own until all of the coefficients given above have been verified.

By definition, $0! = 1$. Therefore,

$$\binom{0}{0} = \frac{1!}{(0-0)!\ 0!} = \frac{1!}{1!} = 1 \text{ for the apex of the triangle.}$$

For the second row,

$$\binom{1}{0} = \frac{1!}{(1-0)!\ 0!} = \frac{1}{1} = 1$$

and

$$\binom{1}{1} = \frac{1!}{1!} = \frac{1}{1} = 1$$

For the third row,

$$\binom{2}{0} = \frac{2!}{(2-0)!\ 0!} = \frac{2}{2} = 1$$

$$\binom{2}{1} = \frac{2!}{(2-1)!\ 1!} = \frac{2}{1} = 2$$

$$\binom{2}{2} = \frac{2!}{(2-2)!\ 2!} = \frac{2}{2} = 1$$

Now, to apply this knowledge to statistics, let us develop a formula for binomial distributions.

If p is the probability that an event will occur in any single trial (called the probability of a success), and if $q = 1 - p$ is the probability that an event will not occur in any one trial (called the probability of a failure), then the probability that the event will occur exactly X times in N trials (that is, that X successes and $N - X$ failures will take place) can be stated as:

$$p\ (r) = nC^{r}\ \ {}_{rp}q^{n-r} = \frac{n!}{r!\ (n-r)!}\,p^rq^{n-r}$$

where:

$r = 0, 1, 2, \ldots, n$; and $n! = n\,(n-1)\,(n-2) \ldots 1$

This equation is sometimes written

$$p\ (r) = C^n{}_r p^rq^{n-r} = \frac{n!}{r!\ (n-r)\ !}\,p^rq^{n-r}$$

or

$$p\ (r) = \binom{n}{r}p^rq^{n-r} = \frac{n!}{r!\ (n-r)!}\,p^rq^{n-r}$$

In any case, you are concerned with combinations of n things taken r units at a time. You can see that $\binom{n}{r}$ is the r^{th} coefficient in the binominal expansion of

$$(q+p)^n = q^n + nC_1q^{n-1}p + nC_2q^{n-2}p^2 + \ldots + p^n$$

The binomial distribution is most frequently used where you have repeated trials of an experiment. For instance, if the event is the occurrence of a head when a fair coin is tossed, the probability is $p = \frac{1}{2}$. If the event is the occurrence of a seven when a pair of honest dice are thrown the probability is $p = \frac{1}{6}$. For example, the probability of getting exactly 2 heads in 6 tosses of a fair coin is

$$6C_2\left(\frac{1}{2}\right)^2\left(\frac{1}{2}\right)^{6-2}=\frac{6!}{2!\,4!}$$

$$\left(\frac{1}{2}\right)^6=\frac{\overset{3}{\cancel{6}}\cdot\cancel{5}\cdot\cancel{4}\cdot\cancel{3}\cdot\cancel{2}}{2\cdot4\cdot3\cdot2}\left(\frac{1}{64}\right)=\frac{15}{64}$$

The probability of getting 4 heads or more in 6 tosses is

$$6C_4\left(\frac{1}{2}\right)^4\left(\frac{1}{2}\right)^{6-4}+6C_5\left(\frac{1}{2}\right)^5\left(\frac{1}{2}\right)^{6-5}+6C_6\left(\frac{1}{2}\right)^6$$

$$=\frac{6!}{4!\,2!}\left(\frac{1}{2}\right)^6+\frac{6!}{5!\,1!}\left(\frac{1}{2}\right)^6+\frac{6!}{6!\,0!}\left(\frac{1}{2}\right)^6$$

$$=\frac{\overset{3}{\cancel{6}}\cdot5\cdot\cancel{4}\cdot\cancel{3}\cdot\cancel{2}}{\cancel{4}\cdot\cancel{3}\cdot\cancel{2}\cdot\cancel{2}}\left(\frac{1}{64}\right)+\frac{6\cdot\cancel{5}\cdot\cancel{4}\cdot\cancel{3}\cdot\cancel{2}}{\cancel{5}\cdot\cancel{4}\cdot\cancel{3}\cdot\cancel{2}}\left(\frac{1}{64}\right)$$

$$+\frac{\cancel{6}\cdot\cancel{5}\cdot\cancel{4}\cdot\cancel{3}\cdot\cancel{2}}{\cancel{6}\cdot\cancel{5}\cdot\cancel{4}\cdot\cancel{3}\cdot\cancel{2}}\left(\frac{1}{64}\right)=\frac{15}{64}+\frac{6}{64}+\frac{1}{64}=\frac{22}{64}$$

$$=\frac{11}{32}$$

The binomial distribution is a discrete probability distribution and is used only when the probability of occurrence of an event can be assumed to be constant. The binomial distribution is also known as the Bernoulli distribution after its discoverer, James Bernoulli.

To find the standard deviation of the binomial distribution, apply the equation

$$\sigma=\sqrt{npq}$$

For example, if we toss a fair coin 100 times, the expected number of heads that will occur is = np = (100) $\left(\frac{1}{2}\right)$ = 50. The standard deviation is

$$\sigma=\sqrt{npq}=\sqrt{(100)\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)}=5$$

For your convenience, some of the properties of the binomial distribution are given in table 1–9.

Exercises (A34):

1. Applying the binominal formula $\frac{n}{r}=\frac{n!}{(n-r)!r!}$, obtain the coefficients for the following: $\frac{3}{1}, \frac{4}{3}, \frac{5}{2}, \frac{6}{3}$.

2. Applying the theory of binomial distributions, what is the probability of getting 3 heads in 8 tosses of a fair coin?

A35. Define the terms in the normal curve or Gaussian distribution and given data, solve problems on the normal distribution.

The Normal Distribution. A great many of the applications of probability to statistical quality control are based on the normal curve or Gaussian distribution defined by the equation

$$y=\frac{1}{\sigma\sqrt{2\pi}}e-\frac{1}{2}(x-\mu)^2/\sigma^2$$

where μ = the mean (sometimes shown as $\overline{X}$), σ = standard deviation, π = 3.14159 ..., and e = 2.71828 ... (the base of the natural, or Napierian logarithms), X = variable.

When the variable X is expressed in terms of standard units, $z = (X - \mu)/\sigma$. The equation can then be written in the so-called standard form as follows:

$$y=\frac{1}{\sqrt{2\pi}}e-\frac{1}{2}z^2$$

We say that z is normally distributed with mean = zero, and variance = to one—i.e., N (0, 1); therefore, $Z=\frac{X-\mu}{\sigma}$ and sigma equals one.

In statistics, the term *normal* is not used in the sense that we would speak of *a normal person,* nor does it imply *an ordinary* or *usual condition* or one *free from abnormalities*. It is simply a technical term given to a frequency distribution whose shape corresponds to that of the so-called normal curve. (A graph of a typical normal curve gives the percentages of the areas under the curve for units of z as: z = - 1 and + 1, z = - 2 and + 2, and z = - 3 and + 3. The graph is shown in fig. 1–16.) The normal curve is a mathematical ideal in which these relationships always hold true. In figure 1–16, the limits "z = − 1 and + 1" represent one standard deviation (σ), measured in both directions from the mean. The limits "z = − 2 and + 2"

TABLE 1–9

SOME PROPERTIES OF THE BINOMIAL DISTRIBUTION

233-73

Mean	$\mu = np$
Variance	$\sigma^2 = npq$
Standard Deviation	$\sigma = \sqrt{npq}$
Moment Coefficient of Skewness	$\alpha3=\frac{q-p}{\sqrt{npq}}$
Moment Coefficient of Kurtosis	$\alpha4= 3+\frac{1-6pq}{npq}$

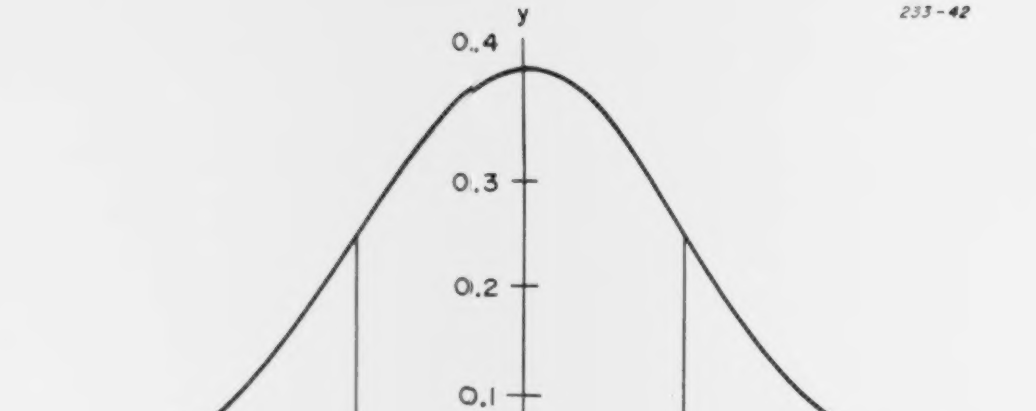

Figure 1–16. The normal curve.

represents two standard deviations (2σ), and $z = -3$ and $+3$ represents three standards deviations (3σ) on either side of the mean. This is true regardless of the shape of the curve. Figure 1–17 shows some of the forms a normal curve can assume. In spite of the apparent peakedness or flatness of these curves, the area between specific σ limits, or ordinates, is the same.

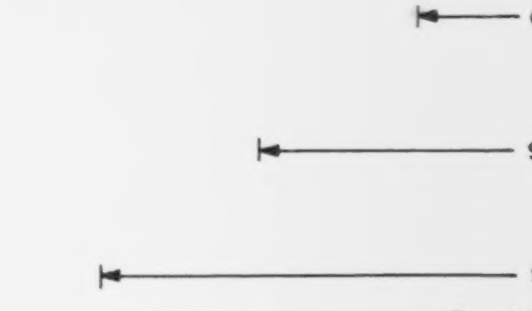

Figure 1–17. Normal curves with the various height-to-width ratios.

The mean of the normal curve is located at the center of the distribution, and if you measure (in terms of standard deviations) the distance to any selected point on the X axis, you can determine the area under the curve included within this distance. In figure 1–17, the mean value is the same for all three distributions. The difference is in the standard deviations. Where $\sigma = 0.25$, all of the data lie very close to the mean; consequently, the curve is tall and narrow. As the individual bits of data extend farther and farther from the mean, the curve becomes shorter and proportionally wider. Thus, the shape of the curve gives you an immediate indication of the nature of the data.

Before we investigate some of the many applications of the normal curve, let us apply the equation and plot a typical curve.

Making use of the table of logarithms in Appendix A, rearrange the equation as follows:

$$\underline{y} = \frac{1}{\sqrt{2\pi}}\,\underline{e} - 1/2\underline{z}^2 \text{ then}$$

$$\log \underline{y} = \log \frac{1}{\sqrt{2\pi}} + \log \underline{e} - 1/1\underline{z}^2 \text{ and}$$

TABLE 1–10

ARRAY OF VALUES OF Y FOR CERTAIN VALUES OF Z

233-74

(1)	(2)	(3)	(4)	(5)
z	$0.2172z^2$	$-(0.2172z^2 + 0.3991)$	log y	y*
0.0	0.0000	−0.3991	0.6009−1	0.399
0.2	0.0087	−0.4078	0.5922−1	0.390
0.4	0.0348	−0.4339	0.5661−1	0.368
0.6	0.0791	−0.4782	0.5218−1	0.332
0.8	0.1390	−0.5381	0.4619−1	0.290
1.0	0.2172	−0.6163	0.3837−1	0.242
1.2	0.3063	−0.7054	0.2946−1	0.197
1.4	0.4257	−0.8248	0.1752−1	0.150
1.6	0.5560	−0.9551	0.0449−1	0.111
1.8	0.7037	−1.1028	0.8972−2	0.079
2.0	0.8688	−1.2679	0.7321−2	0.054
2.5	1.3564	−1.7555	0.2445−2	0.018
3.0	1.9548	−2.3539	0.6461−3	0.004

* Values of y have been rounded off to 3 decimal places

$\log \underline{y} = \log 1 - \log \sqrt{2\pi} - 1/2\underline{z}^2 \log \underline{e}$ and

$\log \underline{y} = -1/2 \log 2\pi - 1/2\underline{z}^2 \log \underline{e}$ and

$\log \underline{y} = -1/2\ (0.7982) - 1/2\ (\underline{z}^2)\ (0.4343)$ and

$\log \underline{y} = -\ (0.3991 + 0.2171\underline{z}^{2)}$

You know that $2\pi = 2\,(3.1416) = 6.2832$, and the log table gives you 0.7982 as the logarithm for that value. It follows that $\frac{\log 2\pi}{2} = \frac{0.7982}{2} = 0.3991$. You also know that $e = 2.71828$, and its logarithm is 0.4343. All you need to do now is substitute the values for z into the equation and calculate the points representing all of y's for all of the values of z.

If you take values of z, such as those listed in the first column of table 1–10 and perform each operation, you can accumulate all of the plotting points you need. The figures in column 2 are obtained by substituting each consecutive value of z into the expression heading the column. Similarly, the expression heading column 3 indicates that the values were obtained by substituting the values from column 2 into the expression heading column 3. The log y values in column 4 are obtained by finding the algebraic sum of the negative values and 1. This is done to change log y, as obtained from the equation, into positive numbers. Remember that mantissas of logarithms must always be positive. This operation gives you the mantissa for the log y and shows you its negative characteristic. The values in column 5 are rounded off antilogs of the log y's.

The next operation is to plot the data you have accumulated. Select a sheet of graph paper having convenient rulings and lay out each individual point. The values you have will describe only one side of the curve, but since each side of the curve is a mirror image of the other, you simply make your plots in pairs, each plot equidistant from the centerline ($z = 0$). After all plots are made, connect them with a smooth curve. The result should resemble the curve in figure 1–18.

Exercises (A35):

1. Define the following terms found in the normal distribution: μ, $\overline{X}$, σ, π, and e.

2. On an examination in a CDC course, the mean was 82 and the standard deviation was 10. Determine the standard scores (i.e., grades in standard deviation units) of students receiving grades (a) 70, (b) 93, (c) 82. Use formula $Z = \frac{x - \mu}{\sigma}$.

3. Referring to exercise 2, find the grades corresponding to the standard scores (a) = − 1 and (b) = 1·6. Use formulas $x - \mu + Z\sigma$.

1–6. Statistical Quality Control

As we discussed earlier, the application of quality control techniques to the process of manufacturing commodities is no new thing. For centuries, craftsmen and artisans have carefully inspected their products and rejected any that did not meet their own standards of quality. But as manufacturing processes became more complicated and as the demand for commodities increased, mass production became necessary. With mass production, it became impractical to inspect every item being manufactured.

233-44

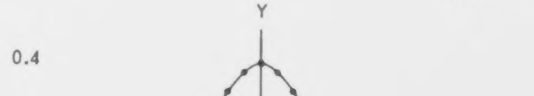

Figure 1–18. Curve of normal probability.

Furthermore, any single product was the result of the efforts of numerous specialists, each incapable of inspecting the product as a whole. Therefore, manufacturers found it necessary to base their quality control procedures on the inspection of selected samples of the production by people specially trained for conducting the inspection. In the imagery production career field, these same principles apply. You are the specially trained inspector. Inspecting samples only tells you something about the quality of the sample, not the entire production. While it is true that you can make inferences about the quality of the total production, unless these inferences are governed by the laws of probability, they are only guesses. Statistical quality control, then, is a procedure for making inferences about a continuing process from samples evaluated in accordance with the laws of probability.

In your work as an imagery production specialist, you must employ various statistical quality control techniques. You now have a basic understanding of the theory of statistics, and all that remains is for you to learn how to apply the theory to practice. We cannot make a statistician of you in this comparatively short course, but we can give you a working knowledge of the use of control charts and statistical tables. We can also acquaint you with certain tests for significance, analyses for variation, and the fundamentals of designing experiments.

A36. Cite the purpose of a control chart for variables and attributes and list the types of variable control charts.

Control Charts. The control chart, as we know it, was first used in 1924 by Doctor Walter A. Shewhart of the Bell Telephone Laboratories. The control chart, sometimes called the Shewhart Chart, is a statistical tool used mainly for the study and control of repetitive processes. The chart is adaptable to a number of different conditions, some of which are concerned with the measurement of variables and some of which record attributes of a controllable process.

Variables. In the language of statistics, we call a control chart that treats measured quality characteristics a chart for variables. Measured quality characteristics can include: dimensions in some unit; values for brittleness of films; density values for, perhaps, a given step-wedge step, or for D max-D min; gamma measurements; quantitative determination in chemical analyses; variations in temperature control; and many other things. In fact, any measurable part of any process that randomly fluctuates around an average value can be recorded on a chart for variables.

Charts for variables are of two types. The first is used in recording average values of samples drawn from a process and is called a chart for averages. The individual observations making up a sample are designated by the symbol X, and an average of individuals is shown as $\overline{X}$ (called X-bar, or bar-X); hence a chart for averages is called an X chart. The second type of chart for variables records the average ranges of the observed individuals and is designated as either a chart for ranges or as an R chart. In our work, the $\overline{X}$ charts and the R charts are the most useful.

Attributes. When sampling to determine defects in a product, we record our findings on a chart for attributes. A chart dealing with the fraction defective is called a *p chart;* and a chart for the number of defects per unit is called a *c chart* in the language of statistics. We will discuss control charts in greater detail in the paragraphs that follow.

Exercises (A36):

1. For what purpose is a chart for variables used?

2. As an imagery production specialist, what two types of variable control charts are you most likely to use?

3. What is the purpose of a control chart for attributes?

A37. State the procedure for accumulating and recording data for control charts.

Charts for Averages ($\overline{X}$). You have two prime reasons for maintaining control charts: first, you want to know that the product you are producing is satisfactory; second, you want some basis for deciding what action, if any, should be taken when a sample seems to be unsatisfactory. How you make these determinations from charts will be explained as we continue our discussion.

Accumulating data. Let us, for the sake of explanation, assume that you are reading the density of the 11th step of the sensitometric strips accompanying the film being processed in your laboratory. For convenience, you might draw up and use a form such as that shown as table 1–11. At each sampling, you make readings of five separate strips and record the values. You also average the readings and enter the average values in the $\overline{X}$ column. Then you subtract the minimum value from the maximum value to obtain the range of each sample and enter it in the R column. Now you have a nice neat compilation of figures; but what does it tell you? Simply that the $\overline{X}$'s as well as the R's fluctuate somewhat. If you want to know the highest $\overline{X}$ reading, or the lowest, you would have to scan the $\overline{X}$ column several times to be sure that 1.37 is the highest, or that 1.34 is the lowest. You can do better than that. You can lay out a graph as shown in figure 1–19 and plot the X values against the sample numbers, and then connect the plots. Now you can see at a glance that the low reading is 1.34 and occurs at the third sampling. Moreover, you can see that the high reading is 1.37 and occurs four times in 20 samplings.

Referring to the R column in table 1–11, you see a column of figures that indicates the difference between the high and low readings of each sampling. If you plot these R values on a graph, such as that shown in figure 1–20, the nature of the differences becomes strikingly apparent. Your immediate impression is probably that you have an erratic

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TABLE 1-11
COMPILATION OF OBSERVED DATA

233-81

Sample No.	11th step density 5 readings per sample					Average $\overline{X}$	Range R
1	1.36	1.39	1.30	1.35	1.36	1.35	.09
2	1.29	1.36	1.37	1.36	1.35	1.35	.08
3	1.36	1.34	1.35	1.29	1.38	1.34	.09
4	1.41	1.38	1.36	1.37	1.32	1.37	.09
5	1.35	1.36	1.31	1.38	1.40	1.36	.09
6	1.41	1.37	1.33	1.36	1.36	1.37	.08
7	1.37	1.38	1.37	1.36	1.33	1.36	.05
8	1.36	1.39	1.35	1.35	1.36	1.36	.09
9	1.31	1.35	1.39	1.38	1.36	1.36	.08
10	1.33	1.35	1.36	1.37	1.35	1.35	.04
11	1.30	1.34	1.36	1.35	1.38	1.35	.08
12	1.37	1.36	1.36	1.35	1.36	1.36	.02
13	1.35	1.37	1.37	1.36	1.35	1.36	.02
14	1.38	1.29	1.34	1.33	1.30	1.37	.09
15	1.36	1.37	1.39	1.36	1.33	1.36	.06
16	1.37	1.37	1.35	1.36	1.36	1.36	.02
17	1.36	1.37	1.40	1.34	1.36	1.37	.06
18	1.32	1.30	1.31	1.35	1.37	1.35	.07
19	1.36	1.35	1.35	1.36	1.37	1.36	.02
20	1.38	1.40	1.35	1.30	1.35	1.36	0.10
Totals						27.17	1.27

$\overline{\overline{X}} = 1.36$ $\overline{R} = 0.06$

process. This may be true, but then, it may not be true. The charts still do not give you the means for evaluating and controlling the process. To make control charts out of them, you must establish a centerline and control limits to indicate (1) the process average and (2) the allowable deviation from that average.

Establishing the centerline and control limits. The centerline on a chart for averages is determined by adding all of the $\overline{X}$'s and dividing by the number of samples. Referring to table 1-11, the total value of the $\overline{X}$'s is 27.17 and the number of samples is 20; therefore, the average of the X's, shown as $\overline{\overline{X}}$ (called X double bar, or double bar X), is

$$\text{Centerline} = \frac{27.17}{20} = 1.36 \text{ (to 2 decimal places)}$$

After having done this, you draw a solid line corresponding to that value on your chart as shown in figure 1-21. Now you can readily see the deviation from the average, or mean, but you still cannot tell whether or not your process is in control. You still need some means of setting down guidelines to tell you if the deviation of a sample exceeds tolerable limits.

Control limits are not arbitrarily set. To be meaningful, they must be based on the performance of a normally behaving process. Earlier, you learned that the results of most processes, if arranged in order of the frequency of their occurrence, describe a "normal" curve. You also learned that this curve can be measured in terms of the standard deviation of the individuals (X's) from the mean ($\overline{X}$). Now, you can see how these standard deviations, which are generated by the process itself, provide the basis for establishing the control limits on your control chart.

To understand exactly what you must do, look at the example in figure 1-22. Here, we have taken the $\overline{X}$'s from table 1-11, and we have arranged them under a normal curve. You can see that the plots under the curve correspond to the plots spread out over the length of the chart. They are the same plots—only the arrangement is different. Obviously, if there is a standard deviation for the plots under the curve, the plots on the chart will also have the same standard deviation. If you choose the s, or σ, lines can be used as control limits. However, there is a danger in using standard deviation derived from sampled process data to calculate control limits for $\overline{X}$ charts. You must realize that using $\sigma = \sqrt{\frac{\Sigma (X - X)^2}{N}}$ (or any of the other deviation

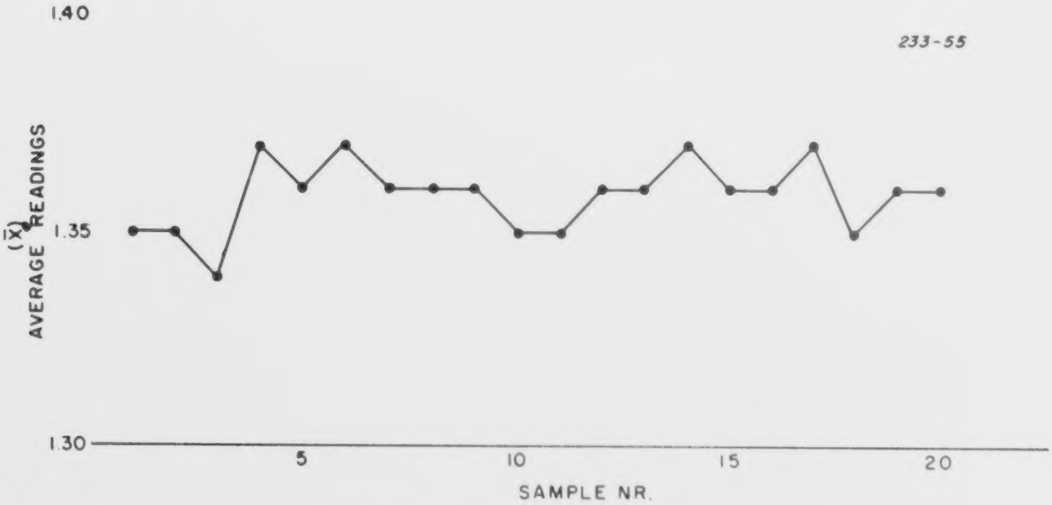

Figure 1-19. Chart showing average step 11 densities versus sample number.

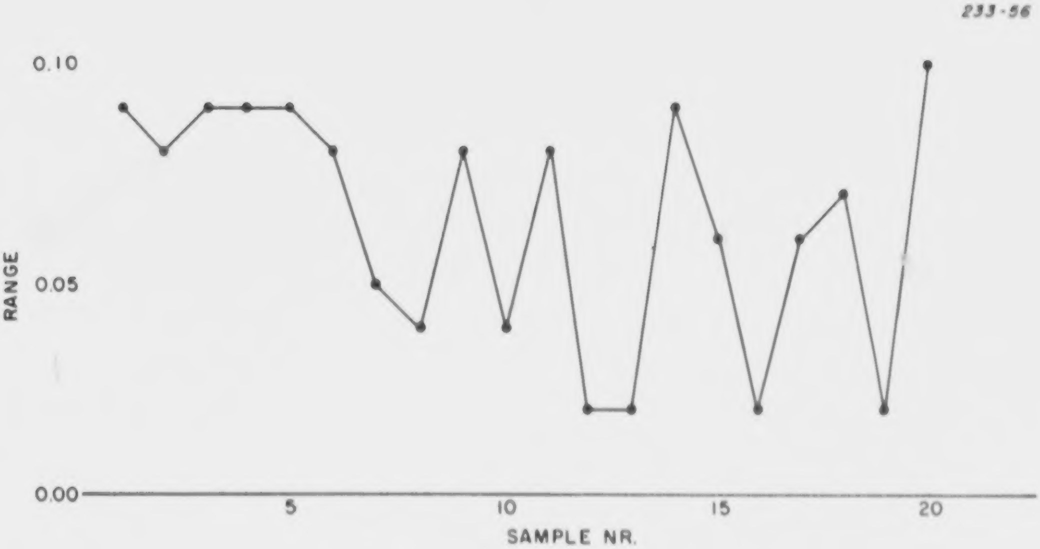

Figure 1-20. Chart showing ranges of step 11 density readings.

formulas discussed) gives you only an estimated standard deviation unless the formula is applied to an entire population. For distributions based on sampled data, this estimation is affected by variations between the means of the samples, and it is unable to show extreme variations in the means. To obtain meaningful control limits for $\bar{X}$ charts, you must consider the "within-sample" variation. The standard deviation formula discloses the "between-sample" variation, and using it for $\bar{X}$ charts generally results in inaccurate control limits being set. You can see that to include the "within-sample" effects, you should base your calculations on data obtained from range charts. Moreover, if the $\bar{R}$ chart shows the process to be out of control, it would be better not to make an $\bar{X}$ chart until process control has been attained. For all new processes, or where you are just beginning to use control charts with an old process, you should determine your control limits from calculations using the average range, and a table such as table 1-12.

For the sake of illustration, we want you to take the data from table 1-11 and set up control charts for which you will calculate control limits. You need both a chart for ranges (fig. 1-20) and a chart for averages (fig. 1-19). You draw in the centerlines for both charts to determine the average range, $\bar{R}$, and the average of the averaged individual observations, $\bar{\bar{X}}$. Then, you apply the formulas:

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R}$$

and

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R}$$

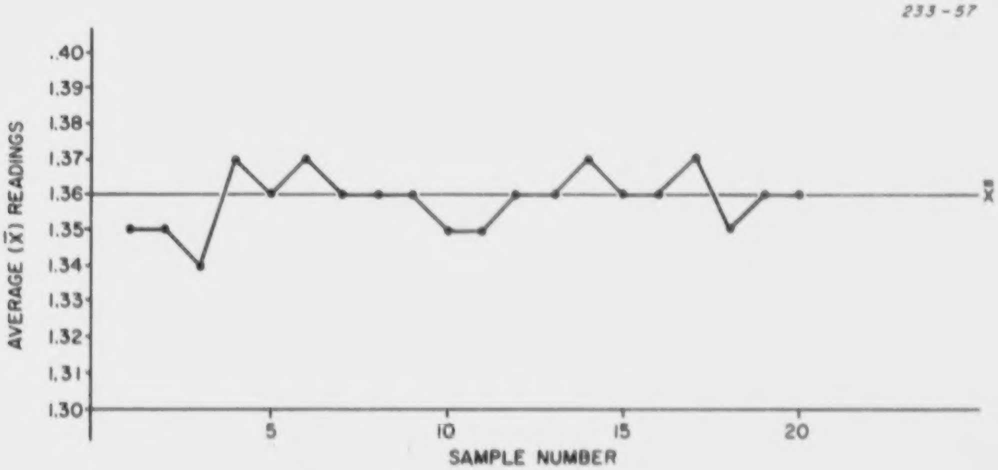

Figure 1-21. Step 11 density chart with centerline plotted.

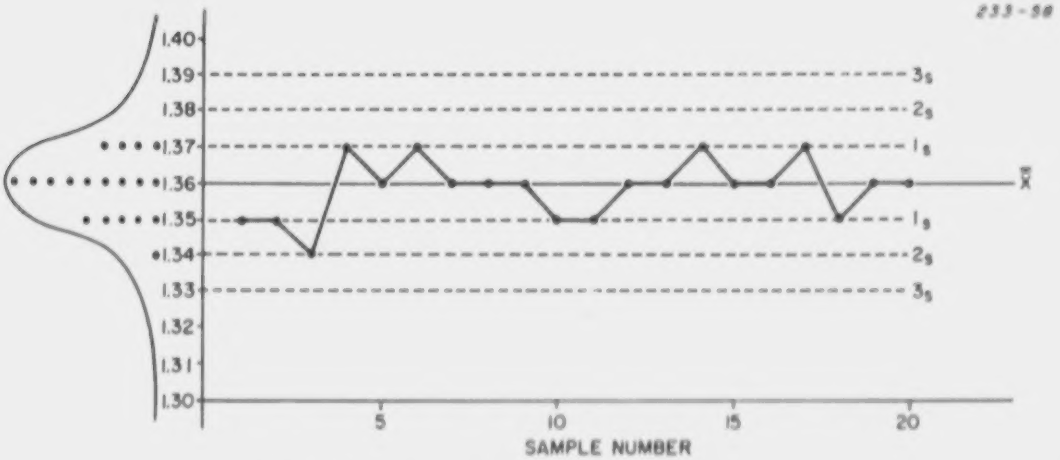

Figure 1-22. Development of control limits based on standard deviation.

where A_2 is the factor for a given sample size taken from table 1-12 to calculate the upper control limits (UCL) and lower control limits (LCL).

Table 1-11 gives the total of the ranges as 1.27. The $\bar{R}$, then, is

$$\bar{R} = \frac{1.27}{20} = 0.06 \text{ (to 2 decimal places)}$$

Also from the table, the total of the $\bar{X}$'s is 27.17 and $\bar{\bar{X}}$ is

$$\bar{\bar{X}} = \frac{27.17}{20} = 1.36 \text{ (to 2 decimal places)}$$

Since your sample size is 5, the A_2 factor is 0.58. Substituting the values into the formula, you get

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R} = 1.36 + 0.58\ (0.06)$$

$$= 1.36 + 0.03 = 1.39$$

and

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R} = 1.36 - 0.58\ (0.06)$$

$$= 1.36 - 0.03 = 1.33$$

Now you can place your control limits on your chart, which should look like figure 1-23. Notice that we have used dashed lines and that they are clearly labeled.

So that you can compare the 3σ limits calculated from the table with those derived from the frequency distribution of the observed data, take the time to work out the standard deviation for the data in the example. Since you are dealing with samples, you should use the formula

$$s = \sqrt{\frac{\Sigma(X - \bar{X})^2}{n - 1}}$$

This formula will tend to compensate for errors that might occur in sampling. Actually, because the individuals (X's) in the example are averages, the formula should read

$$s = \sqrt{\frac{\Sigma(\bar{X} - \bar{\bar{X}})^2}{n - 1}}$$

However, you can simply consider each plot on your chart as being X, and the average of the plots as $\bar{X}$, and use the first of the two formulas as it is written.

TABLE 1-12

FACTOR FOR DETERMINING $3\text{-}\sigma$ CONTROL LIMITS FOR R AND $\bar{X}$ CHARTS

233-82

Number of Observations in Sample, N	Factor for $\bar{X}$ Chart, A_2	Factors for R chart	
		Lower Control Limit D_3	Upper Control Limit D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59

This chart is limited to the factors for $\bar{X}$ and R charts up to sample sizes of 20 observations. The factors are given to 2 decimal places only. Other charts include more factors and often show them to 3 decimal places.

233-59

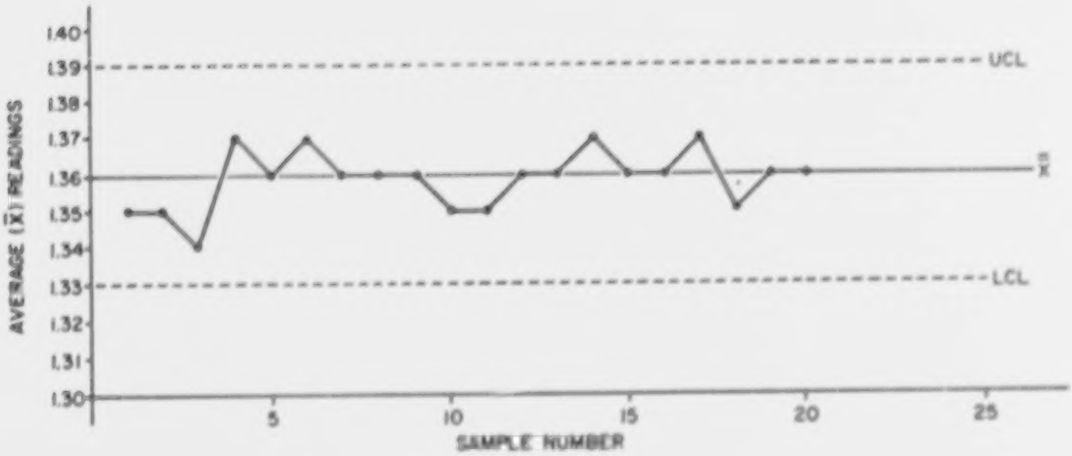

Figure 1-23. $\bar{X}$ chart with centerline, and upper control limits.

This procedure gives you table 1-13, which shows X's, the $\bar{X}$, the values for $X - \bar{X}$, $(X - \bar{X})^2$, and the $\Sigma (X - \bar{X})^2$. Substituting the appropriate values, you get

$$s = \sqrt{\frac{0.0013}{20 - 1}} = \sqrt{\frac{0.0013}{19}}$$

$$= \sqrt{0.000068} = 0.00825 \text{ or } 0.01 \text{ (to 2 decimal places)}$$

TABLE 1-13

VALUES OF $\Sigma (X - \bar{X})^2$ FROM DATA IN TABLE 1-11

233-03

Sample No.	X	$\bar{X}$	$X - \bar{X}$	$(X - \bar{X})^2$
1	1.35	1.36	-0.01	0.0001
2	1.35	1.36	-0.01	0.0001
3	1.34	1.36	-0.02	0.0004
4	1.37	1.36	0.01	0.0001
5	1.36	1.36	0.00	0.0000
6	1.37	1.36	0.01	0.0001
7	1.36	1.36	0.00	0.0000
8	1.36	1.36	0.00	0.0000
9	1.36	1.36	0.00	0.0000
10	1.35	1.36	-0.01	0.0001
11	1.35	1.36	-0.01	0.0001
12	1.36	1.36	0.00	0.0000
13	1.36	1.36	0.00	0.0000
14	1.37	1.36	0.01	0.0001
15	1.36	1.36	0.00	0.0000
16	1.36	1.36	0.00	0.0000
17	1.37	1.36	0.01	0.0001
18	1.35	1.36	-0.01	0.0001
19	1.36	1.36	0.00	0.0000
20	1.36	1.36	0.00	0.0000
			$\Sigma (X - \bar{X})^2$ =	0.0013

This gives you 1's = 0.01, 2's = 0.02, and 3's = 0.03, which, in this case (since the "within-sample" variation is small), corresponds with the 3-σ control limits. Notice that all values obtained in these computations are rounded off to two decimal places. This is reasonable, since the individuals you are working with have no more than two decimal places. In all of your computations, you will work only with significant figures.

Exercises (A37):

1. What is the procedure for accumulating and recording data for control charts?

2. What are the two reasons for maintaining control charts?

A38. State the main purpose of an R chart and cite the procedure for establishing control limits for R charts.

Charts for Ranges (R). Since we have discussed R charts in the foregoing sections, you already know quite a bit about them. You know that the range is the difference between the high and low readings taken in any given period. You have seen how ranges are plotted on a chart, and you know how to find $\bar{R}$, or the average of the ranges. But, aside from using $\bar{R}$ to determine $\bar{X}$ chart control limits, of what use is the R chart? Obviously, the range chart shows you the extent of the variation present within the samples taken. Compared to the $\bar{X}$ chart for the same data, the R chart in figure 1–20 seems very erratic. How do you know if the performance of the operation that produced these plots is good or bad? In all probability, you would say that this chart needs some kind of control limits, and you would be right. Also, your intuition may tell you that you need different control limits for R charts than you need for $\overline{X}$ charts, and once again you would be right. To calculate control limits for ranges, refer to table 1–12.

Establishing control limits. As you examine table 1–12, you see that for ranges, separate factors are used to calculate upper control limits and lower control limits. You also see that for sample sizes of 6 or less, the lower control limit is zero. If, as in the case of the example you are using, the sample size is less than 7, you do not have to calculate the lower control limit. Even if you did, the result would be zero. To calculate R chart control limits, apply these formulas:

$$UCL_R = D_4\overline{R}$$

and

$$LCL_R = D_3\overline{R}$$

where D_3 and D_4 are factors from table 1–12.

Now you apply these equations to the data from table 1–11 and complete the R chart shown as figure 1–20. Substituting the appropriate values, you find that the upper control limit is

$$UCL = D_4\overline{R} = 2.11\ (0.06) = 0.13\ \text{(to 2 decimal places)}$$

where D_4 is 2.11 for a sample size of five selections.

Since you are using the sample size of less than seven selections, your lower control limit is zero. This is indicated by table 1–12. If you attempt to apply the equation $LCL = D_3\overline{R}$ to the date, it works out as follows:

$$LCL = 0\ (0.06) = 0$$

Remember that the product of any number multiplied by zero is always zero.

With the upper and lower control limits calculated, you can place them on your R chart, which will then look like figure 1–24.

Evaluating the R chart. As you examine figure 1–24, several things should become apparent. First, notice that the graph does not seem as loose as it did in figure 1–20 (before the centerline and control limits were placed upon it). It is the same graph, but now you can see that it fluctuates more or less equally about the mean and all plots are well below the upper control limit. You can see immediately that the process is "in control." Next, you should become aware of the path described by the individual plots and look more closely at the plots themselves. Notice that the process starts out with a range that is rather high. This tells you that the difference between the maximum and minimum density readings is large. Then, the second sample shows slight improvement. But the third, fourth, and fifth samples are back up to where the first one was. After that, the process gets better. The sixth, seventh, and eighth samples show less and less variation. Then the range fluctuates widely for the next four samples, becoming quite low for the twelfth and thirteenth samples. Finally, the fluctuations increase, going from one extreme to the other for the next seven samples, with the last being the highest. This is a randomly operating process. At no time was anything done to change it—nor should it have been. Even if some points had been out of control, you

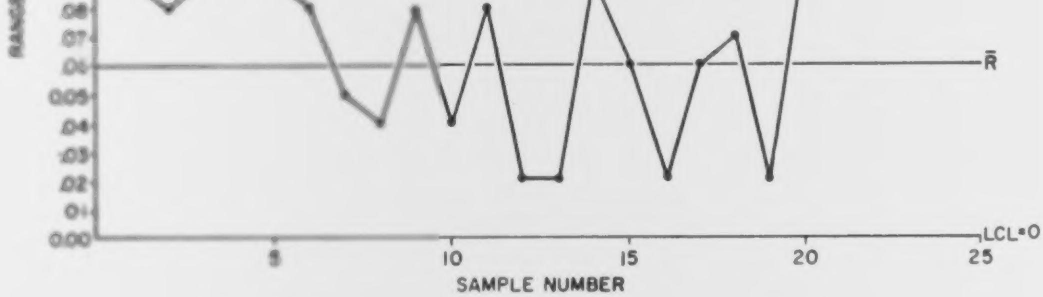

Figure 1-24. R chart of step 11 density readings with centerline and control limits in place.

would have let the process run until you knew for certain that the out-of-control condition was due to an assignable cause and not to a chance variation. This is standard practice whenever you set up controls on a new process or whenever you set up controls for the first time on an old process. The practice is necessary for you to set control limits.

Looking at this chart, what can you expect in the future? Well, since the process is random and within control, you can expect that it will continue as it is going. If this range is satisfactory, you do nothing to change the process. In fact, as long as the same conditions exist—i.e., using the same operators, equipment, chemicals, etc.—you may not be able to change it. But if you should decide that this range is too great, you might try to improve it by altering one or more of the process parameters. You would have to make one change, and then let the process run until you accumulated enough data for a control chart. And you would have to do this for every change you make. If you were successful, you would obtain a graph with random fluctuations, but they would lie much lower on the chart. Your centerline would be lower, and so would your upper control limit. But you can never expect to get a graph with no variation.

The R chart we have been discussing could have shown much more radical fluctuations; even fluctuations with points out of control; and the process might still have produced the same chart for averages seen in figure 1–23. For this reason, both the $\overline{X}$ chart and the R chart are needed for statistical quality control. Let us now consider both charts simultaneously.

Exercises (A38):

1. What is the main purpose of an R chart?

2. How do you establish control limits for R charts?

3. On a range chart, what do plots that are high tell you?

A39. State why you should use $\overline{X}$ and R charts in your quality control procedures.

Evaluation of a Process by Means of $\overline{X}$ and R Charts. According to the $\overline{X}$ chart (fig. 1–23), your process is quite stable. Half of the 20 plots lie on the centerline, and if this were the only chart you saw, you would know nothing of the differences existing within the samples themselves. To illustrate, look at samples 19 and 20. On the $\overline{X}$ chart, both lie on the centerline. Both are equal to the process average. But, sample number 19 had minimum variation while sample number 20 had higher variation than any of the samples tested. Thus, $\overline{X}$ charts show "between-sample" differences while concealing "within-sample" differences. Consequently, it is possible for an $\overline{X}$ chart to show tight control while an R chart for the same data indicates that the process is out of control within samples. Thus, you need both charts for a complete picture of the process.

To point out why both range and average charts are necessary, we have compiled some data from a sampling of hypothetical gamma readings in table 1–14 and have drawn two graphs from the data (fig. 1–25). Notice that most of the points on the $\overline{X}$ chart lie very close to the centerline. In fact, four of the 10 points coincide with it. Only two points seem to be very far away from the mean. Since we have not calculated control limits, we don't know if those points are out of control or not. At any rate, the chart looks quite good. But let's look at the comparable points on the range chart. The first sample plotted is very good. The R chart shows little variation, and the $\overline{X}$ chart shows a point close to the process average. But what about the second sample? The $\overline{X}$ chart shows the plot on the centerline, but the R chart shows that the individuals making up the sample varied a great deal. Obviously, the $\overline{X}$ chart has not told very much about the nature of the five readings making up the sample. The third sample also coincides with the centerline, and the R chart tells that the "within-sample" variation is very small. Again, neither one chart nor the other is sufficient to tell what is happening. Now, look at sample number 4. The $\overline{X}$ chart shows the average reading to be dangerously high, while the R chart shows excellent variability characteristics. Sample number 5 shows that a sample with a low range can also produce an $\overline{X}$ plot that is dangerously low. Thus, the averages of samples 4 and 5 occupy opposite extremes of the $\overline{X}$ chart, while their identical ranges are the best that this process has produced. Plots 6, 7, 9, and 10 are about what you would normally expect from a process. The $\overline{X}$'s lie close to the process average and the range is neither high nor low. But what about sample number 8? Here, the range is extremely high, which would indicate poor control. But the $\overline{X}$ plot, coinciding as it does with the $\overline{X}$ line, would never tell you that. This example is not typical. We have purposely created it to show you what you can expect to learn from control charts and what you can expect control charts to conceal from you and to impress upon you that you need both $\overline{X}$ and R charts for quality control.

Exercises (A39):

1. Why should you use both $\overline{X}$ and R charts in your quality control procedures?

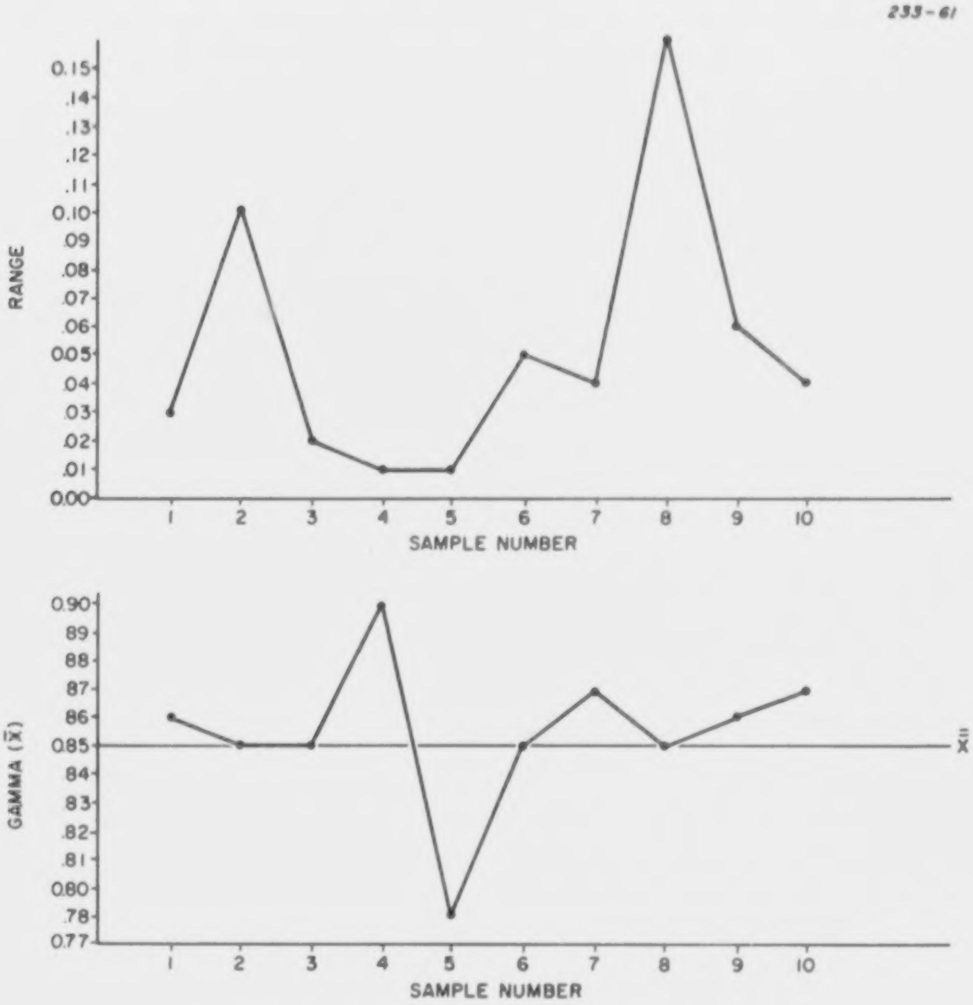

Figure 1-25. Comparision of ranges and averages of hypothetical density readings.

TABLE 1-14

HYPOTHETICAL GAMMA READINGS SHOWING RANGES AND AVERAGES OF SAMPLES

233-84

Sample No.	Gamma (X)					($\bar{X}$)	R
1	0.85	0.85	0.88	0.86	0.85	0.86	0.03
2	0.80	0.90	0.85	0.86	0.84	0.85	0.10
3	0.86	0.86	0.84	0.85	0.84	0.85	0.02
4	0.90	0.91	0.90	0.90	0.91	0.90	0.01
5	0.79	0.78	0.78	0.79	0.78	0.78	0.01
6	0.82	0.86	0.83	0.86	0.87	0.85	0.05
7	0.87	0.86	0.85	0.86	0.89	0.87	0.04
8	0.85	0.93	0.86	0.77	0.84	0.85	0.16
9	0.82	0.87	0.85	0.88	0.88	0.86	0.06
10	0.86	0.87	0.87	0.85	0.89	0.87	0.04

A40. List the two general types into which statistical tables fall and cite the kind of information that is contained in general-purpose statistical tables and special-purpose statistical tables.

Statistical Tables. In the application of statistical control measures, you will use a great number of tables of various kinds. Many of these are general in nature, and many are constructed for some specific purpose. In the following paragraphs, you will learn about both the general-purpose and special-purpose statistical tables, and you will be given some rules for constructing these tables.

General-purpose tables. Your main reason for using a general-purpose table (sometimes called a primary table) is to present original data in a convenient form for reference purposes. Being a source of information concerning original data, general-purpose tables are used in the construction of special-purpose tables.

Characteristically, a general-purpose table contains a variety of information about one subject. The figures it contains are absolute (not percentage) figures; and they should be actual figures (not rounded-off numbers). The information should be presented in such a way that you can easily use it for reference purposes.

Special-purpose tables. In practice, you would construct a special-purpose table to point up particular phases of the data derived from general-purpose statistical tables. The presentation should display the selected data in a simple, readily understandable form.

Unlike the requirements for general-purpose tables, special-purpose tables permit you to round off numbers (1) to facilitate interpretation and (2) to condense data to significant numbers. For example, a general-purpose chart may show a tabulation of Δ D's, Δ log E's, and γ's. Suppose you have $\Delta D = 0.85$ and $\Delta \log E = 0.91$. The gamma, as derived from these values, is $\gamma = 0.934$ and would appear that way on your general-purpose chart. However, gamma is always shown to two decimal places only, and your special-purpose chart (in this case, a chart for gammas) would show that $\gamma = 0.93$.

Constructing statistical tables. The following rules for constructing statistical tables are not rigid. You may vary them whenever necessary to suit some particular practice of your own, or you may vary them when the practices of your organization have established a different format. In general, the example shown in figure 1-26 is acceptable in any statistical quality-control procedure, and the following rules apply.

a. Be sure that the title is self-explanatory and includes (1) the nature of the data presented, (2) the locality in which the data were accumulated, and (3) the time period involved.

b. Except where you are reporting original data you have generated yourself, always show the source of the material. This provides an authority for the data, a means of verification, and a reference for additional material.

c. When necessary, place footnotes immediately beneath the table. Always indicate the footnote by symbols (such as

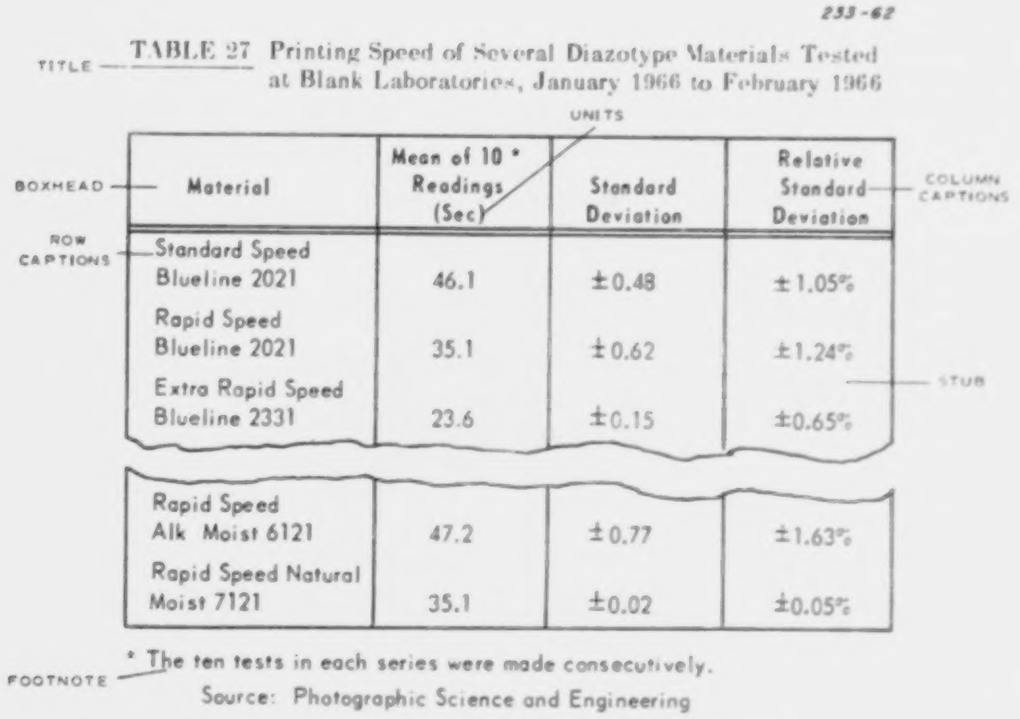
233-62
TITLE
UNITS
BOXHEAD
COLUMN CAPTIONS
ROW CAPTIONS
STUB
FOOTNOTE

TABLE 27 Printing Speed of Several Diazotype Materials Tested at Blank Laboratories, January 1966 to February 1966

Material	Mean of 10 * Readings (Sec)	Standard Deviation	Relative Standard Deviation
Standard Speed Blueline 2021	46.1	±0.48	±1.05%
Rapid Speed Blueline 2021	35.1	±0.62	±1.24%
Extra Rapid Speed Blueline 2331	23.6	±0.15	±0.65%
Rapid Speed Alk Moist 6121	47.2	±0.77	±1.63%
Rapid Speed Natural Moist 7121	35.1	±0.02	±0.05%

* The ten tests in each series were made consecutively.

Source: Photographic Science and Engineering

Figure 1-26. Example of a statistical table taken from a technical report.

*, #, etc.) or by a letter of the alphabet. Never use a number because of the possibility of confusing the footnote number with the numbers of the table.

d. Your first consideration in arranging the items in your table is ease in reading, comparison, and analysis of data. The items may be arranged in the following five ways, depending upon the nature of the data and the purpose of the table.

(1) Alphabetically. General-purpose tables are frequently arranged according to the alphabetical order of the items.

(2) Chronologically. Much of your work involves accumulating data continuously throughout a processing run. Such data are presented in increments of time.

(3) Geographically. Although seldom applicable to photographic activites, geographic arrangement of items may be used when appropriate.

(4) By magnitude. When items are arranged according to size, they may be either in order of increasing or decreasing magnitude. For example, in a table in which the row captions are class intervals in a frequency distribution, the numbers start with the smallest at the top and increase in size as they progress downward; or they start at the left and increase in size as they go to the right. In some tables, numbers may start with the smallest in the upper left corner and increase both to the right and downward. Since graphs are so arranged, it is sometimes convenient to list data in order of decreasing magnitude, i.e., with the largest numbers at the top of the column (or the left) and the smallest at the bottom of the column (or the right).

(5) By custom. In some instances, there is a customary classification for types of data which do not follow any serial arrangement. For example, the normal classification sequence is men, women, and children. This classification is seldom, if ever, listed in the order women, children, and men, or the order children, women, and men.

e. When your table contains a large number of columns, it is permissible, and often advisable, to give each column a number or letter for easy reference.

f. The heading of each column in the boxhead is called the column caption. Column captions should be concise and self-explanatory. If your table contains a miscellaneous column, it should be placed at the extreme right of the table.

g. The body of the table is called the stub, and the heading of each row is known as the row caption. When the stub contains a large number of items, arranging them in groups makes the data easier to read and interpret.

h. When the data in your table are totaled, the row totals appear at the extreme right and the column totals are placed at the bottom of the table.

i. The units of measurement should appear in the boxhead just under the column captions.

j. In general, statistical tables are constructed with lines ruled as follows:

(1) A single horizontal line is placed below the title and below the body of the table.

(2) Single lines are used to separate the columns. (In typewritten or printed tables, these lines are sometimes omitted.)

(3) A double line, or a heavy line, is used to separate the boxhead and the stub.

(4) Totals are separated from the other figures in a column by a single line.

k. When you desire to emphasize certain elements of a table, you may make them stand out by using heavy lines, double lines, italics, or contrasting boldface and lightface type. But be sure that the system you use emphasizes, and does not confuse, the items you wish to point out.

The tables we have discussed in the foregoing paragraphs are those you are likely to construct in the course of your work. Also included under the classification of statistical tables are those tables that have been compiled for your convenience. Among these are tables such as the tables for "Array of Values of Y for Certain Values of Z" (table 1–10), "Factors for Determining 3-σ Control Limits for R and $\overline{X}$ Charts" (table 1–12), and others. You should have many such tables available and should make use of them whenever possible.

Exercises (A40):

1. List the two general types into which statistical tables fall.

2. What kind of information is contained in general-purpose statistical tables?

3. What are special-purpose statistical tables used for?

A41. Name the tests used when testing to make statistical decisions about processes based upon whether significant changes have occurred.

Test of Significance. Frequently, in the course of controlling a process, you may be called upon to make decisions about populations from the information obtained from samples. For example, changing a developer formula could change the character of your product. Before you committed your laboratory to the use of the new formula, you would want to be reasonably sure that it would not change the product. In other words, you would make a statistical decision concerning the change in formula. Also, you might have to decide which of two processing machines is the better—or if three processing machines are actually turning out the same product quality. In the precise operations of your laboratory, you must produce work that does not differ significantly from one machine to another; from one operator to another; and from one day to another. To do this, you must occasionally make tests to discover if any significant change in the process has occurred. Such tests are called tests of significance or test of hypothesis.

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Exercises (A41):

1. When testing to make statistical decisions about processes based upon whether significant changes have occurred, what tests would you use?

A42. Define null hypothesis.

Null Hypothesis. To conduct a test of significance, the first step is to establish a statistical hypothesis and then try to prove or disprove it. If you state the hypothesis that there is no difference between processes, you have formulated what is called a null hypothesis. In so doing, you automatically imply an opposite hypothesis—that there is a difference between processes. Any hypothesis that differs from a given hypothesis is called the alternative hypothesis, and if you prove one, you disprove the other. In tests of significance, the null hypothesis is denoted H_0, and the alternative hypothesis is denoted H_1.

Exercises (A42):

1. Define null hypothesis.

A43. State the difference between type I and type II errors.

Type I and Type II Errors. Whenever you make statistical decisions on the basis of samples, you must realize that you could be wrong. In tests of hypotheses, if you reject a hypothesis that should have been accepted, you have committed a type I error. Type I errors are also called errors of the first kind, and alpha (α) errors. If you accept a hypothesis that should have been rejected, you have made a type II error. Type II errors are also called errors of the second kind and beta (β) errors. In either case, you have made an error in judgement or a wrong decision.

For any tests of significance or hypothesis to be good, they must be designed in such a way that they minimize these errors of decision. This is difficult since, for a given sample size, any attempt to decrease one type of error generally results in increasing the other type. You might decrease both types of error by increasing the sample size, but this is not always practical. The usual procedure is to determine beforehand how much of a risk of being wrong you are willing to accept and design a test accordingly.

Exercises (A43):

1. What is a type I error? A type II error?

A44. Designate an *a* risk to the 0.05 significance level.

Significance Levels. If you decide to limit the risk of committing a type I error to 5 percent (0.05) or to 1 percent (0.01), you are setting the level of significance of the test. You generally set the desired level (denoted by the symbol *a* before taking any samples, so that the results you obtain will not influence your decision.

Generally, an *a* level is set at the 5-percent level of significance, which means you have 1 chance in 20 of rejecting a hypothesis that should be accepted. In other words, you are 95-percent confident that you are making the right choice. You can also say that you reject the hypothesis at a 0.05 level of significance, which means that there is a probability of 5 percent that you could be wrong.

The risk of committing a type II error varies with experimental and operational conditions, and you must determine the risk as a function of those conditions. Since it is more convenient to do so, most statisticians prefer to test the null hypothesis at the *a* significance level.

Exercises (A44):

1. What do you mean when you are taking an *a* risk to the 0.05 significance level?

A45. Name the test used to conduct significance tests involving normal distributions.

Significance Tests Involving the Normal Distribution. To pursue the problem of significance testing further, let us assume the following conditions. For a given hypothesis, you obtain a sampling distribution which can be considered normal. You plot the curve and it comes out as shown in figure 1–27. This is a normal curve showing the distribution of the standardized variable or z score. You can see from the figure that, if the hypothesis is true, you can be 95-percent confident that the z score of an actual sample statistic, s, will lie between -1.96 and 1.96, inasmuch as this area under the normal curve equals 0.95 of the total area. If you selected a single sample at random and found that its statistic fell outside the area between -1.96 to 1.96, you would conclude that, if your hypothesis were true, such an occurrence could happen with a probability of only 0.05 (as indicated by the shaded areas of the curve). You would decide that this z score was significantly different from what you would expect, and you would most likely reject the hypothesis.

Thus, you see that the total shaded area, 0.05, is the significance level of the test. It represents the probability of your incorrectly rejecting the hypothesis; that is, the probability of committing a type I error. If you reject a hypothesis on the basis of a sample falling in this area, we say that the hypothesis is rejected at a 0.05 level of significance or that the z score of the sample statistic is significant at a 0.05 level of significance.

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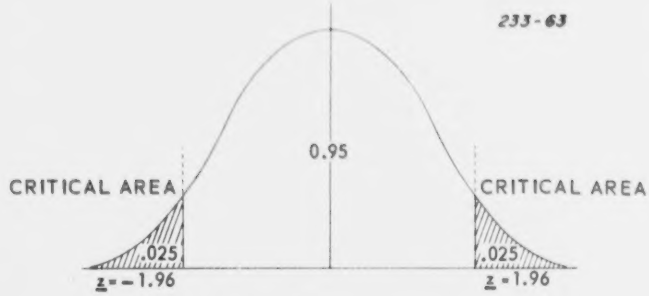

Figure 1–27. Distribution of the standardized variable (z score).

The set of z scores lying outside the range −1.96 to 1.96 comprises what we call the critical region, the region of significance, or the region of the rejection of the hypothesis. On the other hand, the set of z scores lying inside the range from −1.96 to 1.96 comprises the region of nonsignificance or the region of acceptance of the hypothesis.

Now we can supply you with a rule for conducting tests of hypothesis or significance. Reject the hypothesis at a 0.05 level of significance if the z score of the statistic, s, is greater than 1.96 ($z > 1.96$) or less than −1.96 ($z < -1.96$); otherwise, accept the hypothesis (or make no decision at all). Because of its importance in hypothesis and significance testing, the z score is also called a test statistic.

As you realize, other levels of significance can be used. For instance, if you use a 0.01 significance level, you would reject the hypothesis if the z score fell outside of the range from −2.58 to 2.58. Table 1–15 provides the critical values for some of the levels of significance you may have occasion to use. If your requirements include more significance levels than these, consult complete tables such as those found in AFM 52–2, *Principles and Practices for Precision Photographic Processing Laboratories*, Volume 2, or in the textbooks on statistics. (NOTE: This manual is obsolete; used for training purposes only.)

Exercises (A45):

1. What test statistic do you use in significance tests of normal distributions?

A46. Name the test statistic used when hypothesis testing, sample versus population, σ is known.

Testing Sample Versus Population if σ is Known. To illustrate an application of significance testing, let's set up a typical problem. Suppose that after mixing chemicals for a processing machine over a long period of time and testing every batch, you find that the average for pH is 9.80 and σ is 0.425. After changing your source of supply for chemicals, you take 10 samples of your solutions and discover that the average pH has dropped to 9.36. You want to know (1) if this change will affect your process or (2) if it will make no significant difference. Your first step is to set up your null hypothesis. You start by saying that the average of the samples ($\overline{X}$) is equal to the average of the population (μ). Then the alternate hypothesis is that the sample average is not equal to the population average. This

TABLE 1-15

SOME PROBABILITIES OF THE NORMAL PROBABILITY DISTRIBUTION

233-85

Level of Significance α	.10	.05	.01	.005
One-tailed Tests: Critical values for Z (Book Values)	−1.28 or 1.28	−1.645 or 1.645	−2.33 or 2.33	−2.58 or 2.58
Two-tailed Tests: Critical values for Z (Book Values)	−1.645 and 1.645	−1.96 and 1.96	−2.58 and 2.58	−3.08 and 3.08

* Areas under the normal curve from $-\infty$ to Z.

is a two-tailed test, since you would reject H_0 if H_1 is such that: $X > \mu$, or $X < \mu$. Symbolically, these hypotheses are shown:

$$H_0, \bar{X} = \mu$$
$$H_1, \bar{X} = \mu$$

Since you are dealing with a population whose σ you know, you will use the test statistic

$$z = \frac{\bar{X} - \mu}{\sigma/\sqrt{N}}$$

Substituting the data from the problem, the equation becomes:

$$z = \frac{9.36 - 9.80}{0.425\sqrt{10}} = \frac{-0.44}{0.425/3.162} = \frac{0.44}{0.134} = 3.284$$

(Since you are interested only in the deviation of the sample average from the population average, you can use the absolute value for 9.36 − 9.80, which is 0.44, and the negative sign, −, is unnecessary.)

If you selected a 5-percent (0.05) level of significance, your tabular (or book) value for z is −1.96 and 1.96 (see table 1–15). Your calculations show that your z score, 3.284, is greater than the book value for z, 1.96. Therefore, you would reject the null hypothesis. You might conclude that the new chemicals make a significant difference and, therefore, should not be used.

Exercises (A46):

1. When hypothesis testing, sample versus population, σ known, what test statistic should you use?

A47. Name the test statistic used when hypothesis testing, sample versus population, σ is unknown, and cite the action to take to reject a null hypothesis after conducting a significance test.

Testing Sample Versus Population if σ is Unknown. If you do not know the σ of the universe, you must proceed differently. Instead of obtaining a z score using the test statistic $z = \frac{\bar{X} - \mu}{\sigma/\sqrt{N}}$, you must run a *t test* using the test statistic $t = \frac{\bar{X} - \mu}{S/\sqrt{N}}$. This means that you must calculate both the mean and the standard deviation of your sample before determining the t score.

Let's suppose that in the problem in the previous segment, you did not know σ. Let's suppose, also, that for a sample of 10, you determine that $\bar{X} = 9.30$ and $s = 0.027$. You are now ready to substitute values into the equation.

Thus,

$$t = \frac{\bar{X} - \mu}{s/\sqrt{N}} = \frac{9.30 - 9.36}{0.027/\sqrt{10}} = \frac{-0.06}{0.027/3.162}$$
$$= \frac{0.06}{0.0085} = 7.06$$

Your calculated t score is 7.06. To relate this to meaningful information, you must first decide upon the acceptance limit you wish to use, and then you must consult a table of percentage points of the t distribution (table 1–16).

Table 1–16 gives the significance values directly for a two-tailed test. To read it, you simply read down the column headed by your selected acceptance level (in this case, 0.05) to where it intersects with the line containing the number equal to the sample size less the degrees of freedom. Since you are working with N − 1 degrees of freedom and your sample size is 10, the N − 1 line will be 10 − 1, or 9 in the n column. The value 2.262 appears on the 9 line in the column headed .05. This is the book value, and you should report it as: t = 0.05; value for 9 = 2.262. Your calculated t, 7.06, is larger than the book t, indicating that there is a significant difference resulting from the use of the new chemicals; therefore, you must reject the null hypothesis.

Now, you should be asking some questions. What should I do now? Should I throw out the new solutions and go back to the old chemicals? Should I question this result and run additional tests? These are legitimate questions that should be answered. If there is any validity to significance testing, you must use the information it gives you to make such decisions. In this case, you find that a significant difference exists and should be taken care of. You might reject the offending chemicals and go back to the old ones, but in the Air Force, this is not always possible. If you must use the new chemicals, you can adjust the pH by chemically modifying the solutions (see the volume of this course covering chemistry), and you would be 95 percent sure that you were doing the right thing. Or, since validity increases as sample size increases, you could decide to take more samples and run additional tests. If you were to repeat the test with, say, 25 samples, you should be more certain that the results reflect the true condition of the solutions. Realize that with any statistical tests, larger samples give truer answers.

Earlier, we decided that the reason for testing was to learn whether or not the pH difference would affect the process. If you find from your hypothesis testing that a significant difference does exist, is this fact alone sufficient justification for deciding that the process will be adversely affected? Probably not. To be sure, you should run sensitometric tests on the product, and if a difference exists there, you should also run statistical tests to see if that difference is significant. Remember, statistical testing only gives you information that you can use *to assist* you in making wise decisions. Still you could be wrong once out of 20 times.

Exercises (A47):

1. When hypothesis testing, sample versus population, σ is unknown, what test statistic should you use?

TABLE 1-16
PERCENTAGE POINTS OF THE t DISTRIBUTION

233-86

Probability.

n	·9	·8	·7	·6	·5	·4	·3	·2	·1	·05	·02	·01	·001
1	·158	·325	·510	·727	1·000	1·376	1·963	3·078	6·314	12·706	31·821	63·657	636·619
2	·142	·289	·445	·617	·816	1·061	1·386	1·886	2·920	4·303	6·965	9·925	31·598
3	·137	·277	·424	·584	·765	·978	1·250	1·638	2·353	3·182	4·541	5·841	12·924
4	·134	·271	·414	·569	·741	·941	1·190	1·533	2·132	2·776	3·747	4·604	8·610
5	·132	·267	·408	·559	·727	·920	1·156	1·476	2·015	2·571	3·365	4·032	6·869
6	·131	·265	·404	·553	·718	·906	1·134	1·440	1·943	2·447	3·143	3·707	5·959
7	·130	·263	·402	·549	·711	·896	1·119	1·415	1·895	2·365	2·998	3·499	5·408
8	·130	·262	·399	·546	·706	·889	1·108	1·397	1·860	2·306	2·896	3·355	5·041
9	·129	·261	·398	·543	·703	·883	1·100	1·383	1·833	2·262	2·821	3·250	4·781
10	·129	·260	·397	·542	·700	·879	1·093	1·372	1·812	2·228	2·764	3·169	4·587
11	·129	·260	·396	·540	·697	·876	1·088	1·363	1·796	2·201	2·718	3·106	4·437
12	·128	·259	·395	·539	·695	·873	1·083	1·356	1·782	2·179	2·681	3·055	4·318
13	·128	·259	·394	·538	·694	·870	1·079	1·350	1·771	2·160	2·650	3·012	4·221
14	·128	·258	·393	·537	·692	·868	1·076	1·345	1·761	2·145	2·624	2·977	4·140
15	·128	·258	·393	·536	·691	·866	1·074	1·341	1·753	2·131	2·602	2·947	4·073
16	·128	·258	·392	·535	·690	·865	1·071	1·337	1·746	2·120	2·583	2·921	4·015
17	·128	·257	·392	·534	·689	·863	1·069	1·333	1·740	2·110	2·567	2·898	3·965
18	·127	·257	·392	·534	·688	·862	1·067	1·330	1·734	2·101	2·552	2·878	3·922
19	·127	·257	·391	·533	·688	·861	1·066	1·328	1·729	2·093	2·539	2·861	3·883
20	·127	·257	·391	·533	·687	·860	1·064	1·325	1·725	2·086	2·528	2·845	3·850
21	·127	·257	·391	·532	·686	·859	1·063	1·323	1·721	2·080	2·518	2·831	3·819
22	·127	·256	·390	·532	·686	·858	1·061	1·321	1·717	2·074	2·508	2·819	3·792
23	·127	·256	·390	·532	·685	·858	1·060	1·319	1·714	2·069	2·500	2·807	3·767
24	·127	·256	·390	·531	·685	·857	1·059	1·318	1·711	2·064	2·492	2·797	3·745
25	·127	·256	·390	·531	·684	·856	1·058	1·316	1·708	2·060	2·485	2·787	3·725
26	·127	·256	·390	·531	·684	·856	1·058	1·315	1·706	2·056	2·479	2·779	3·707
27	·127	·256	·389	·531	·684	·855	1·057	1·314	1·703	2·052	2·473	2·771	3·690
28	·127	·256	·389	·530	·683	·855	1·056	1·313	1·701	2·048	2·467	2·763	3·674
29	·127	·256	·389	·530	·683	·854	1·055	1·311	1·699	2·045	2·462	2·756	3·659
30	·127	·256	·389	·530	·683	·854	1·055	1·310	1·697	2·042	2·457	2·750	3·646
40	·126	·255	·388	·529	·681	·851	1·050	1·303	1·684	2·021	2·423	2·704	3·551
60	·126	·254	·387	·527	·679	·848	1·046	1·296	1·671	2·000	2·390	2·660	3·460
120	·126	·254	·386	·526	·677	·845	1·041	1·289	1·658	1·980	2·358	2·617	3·373
∞	·126	·253	·385	·524	·674	·842	1·036	1·282	1·645	1·960	2·326	2·576	3·291

This table is reprinted with permission from Table III of R. A. Fisher and F. Yates "Statistical Tables for Biological, Agricultural and Medical Research" (Edinburgh: Oliver & Boyd, Ltd.).

TABLE 1-17

MELTING POINTS OF HYDROQUINONE (3 READINGS - 4 THERMOMETERS)

233-87

THERMOMETERS

READINGS	A	B	C	D	GRAND TOTAL
	173.0	172.0	171.0	172.5	
	174.0	173.0	171.5	173.5	
	173.5	173.0	173.0	171.0	
Totals					

2. Suppose that after conducting a significance test, you find it necessary to reject the null hypothesis. What does this mean? What action should you take because of it? Explain.

A48. State the method to compute significance and cite the 10 steps of an orderly analysis of variance.

Analysis of Variance. Through hypothesis testing, you are able to decide whether or not significant differences exist in the processes you are trying to control. But recognize that such tests have limitations; and when there are several variables present, you can extend your control by applying the appropriate "analysis of variance" to the data you are studying. Analysis of variance consists of classifying and cross-classifying data and of applying the correct formula to compute significance. The process is complex but not excessively difficult. However, you must be orderly in setting up your problem, and you must carry out your computations with painstaking care.

To establish a system for the process of computing analyses of variance, we suggest that you go through steps as presented in the following example.

a. Present the data. Accumulate the data to be studied and arrange them in an orderly table. Table 1–17 illustrates the data for a single-factor analysis.

b. Determine your objective. From the data in table 1–17, you would want to know if the thermometers used give divergent readings or if the differences resulted from normal random sampling variations.

c. Design the model. You must set up an equation to give you the information needed to obtain your stated objective. For a single-factor analysis, you would say that the variable you are testing, which includes the effect of all the data in the rows and columns of the table (X_{ij}), is equal to the general mean (μ) plus the column effect (v_j) plus the random error, residual, and chance variations (ϵ_{ij}). The equation for the model is

$$X_{ij} = \mu + v_j + \epsilon_{ij}$$

d. State the hypothesis. The null hypothesis is that there is no significant difference in the accuracy of the thermometers, i.e., the column effect (v_j) is zero. The alternative hypothesis is that the thermometers do read differently and that the column effect does not equal zero. In this case, the column effect is greater than zero. Symbolically, the hypotheses are shown

$$H_0 : v_j = \Theta$$

$$H_1 : v_j \neq \Theta$$

e. Define the nomenclature. The following symbols are generally used in analysis of variance.

X = an individual value
N = total number of individual values
T = grand total
r = number of rows
c = number of columns
T_j = total for the jth column
Q_c = sum of squares for columns
Q_T = total sum of squares
Q_o = residual sum of squares

The first five symbols need no special explanation but the remaining four do. The symbol T_j (described as the total for the jth column in the language of statistics) is the total for each column in the table. The symbol Q_c is the sum of squares of the deviation of the individuals from the column mean and is derived from the equation:

$$Q_c = \frac{\Sigma T_j^{\,2}}{r} - \frac{T^2}{N}$$

or

$$Q_c = \frac{1}{r}\,\Sigma T^2_j - \frac{T^2}{N}$$

This tells you to: (1) square the column totals, (2) sum them, (3) divide by the number of rows (or multiply by 1 over the number of rows), and (4) subtract the correction factor T^2. By using the correction factor, you can use a short method for determining the sum of squares. Otherwise, you would have to find the deviation of each individual, square each, and add them all together. The total sum of squares, Q_T (sometimes shown simply as Q), is given as:

$$Q_T = \Sigma X^2 - \frac{T^2}{N}$$

and is the sum of each individual squared, minus the correction factor $\frac{T^2}{N}$. The symbol Q_o describes residual variation or variation other than that resulting from column variation. It is given as:

ANOVA TABLE

Source	Sum of Squares	Degrees of Freedom df	Mean Square
(Variable)			
Residual			
Total			

Figure 1–28. Accepted format for a single-factor ANOVA table.

$$Q_o = Q_T - Q_c$$

Subtracting the sum of squares for columns from the total sum of squares gives you a value for the variation attributable to other reasons.

f. Perform the calculations. Compute the values for Q_T, Q_c, and Q_o, using the equations given in step *e*.

g. Determine degrees of freedom. The degrees of freedom for columns is given:

$$df_c = c - 1$$

The degrees of freedom for the total is given:

$$df_T = N - 1$$

The degrees of freedom equation for residual is:

$$df_{resid} = (n - 1) - (c - 1)$$

h. Prepare an ANOVA table. ANOVA is a coined word derived from ANalysis Of VAriance, and an ANOVA table is an analysis of variance table. The ANOVA table is an orderly presentation of all of your essential analysis of variance calculations and is prepared in the format shown in figure 1–28. The table provides space for the sum of squares, degrees of freedom, and mean square of both the variable being tested and the residual variable. In addition, the table provides space for totals for sum of squares and degrees of freedom obtained from your calculations. You obtain the mean square by dividing the sum of squares by the degrees of freedom.

i. Apply the F test. To perform the F test, find the ratio of the mean squares. Always divide the larger value by the smaller one, and state the quotient as the computed F. Then consult table 1–18 for the book F. (Table 1–18 gives F values for 0.05 significance level. For other significance levels, tables in other publications should be consulted.) To use the table, locate the degrees of freedom for the numerator at the top of the page and the degrees of freedom for the denominator on the left side of the page. Trace down and across and find the book F at the point of intersection.

j. Draw your conclusions. If your calculated F is smaller than the book F, you can say, with a 5-percent chance of being wrong, that there is no significant difference between the variables and that the null hypothesis should be accepted. If the calculated F is larger than the book F, reject the null hypothesis and take additional action as cited previously.

Exercises (A48):

1. In analysis of variance, by what method do you compute significance?

2. Name the 10 steps of an orderly analysis of variance.

A49. Explain the formula $\frac{T^2}{N}$ and the symbol T_j and specify how to compute (a) the sum of the squares for the columns, (b) the total sum of squares, and (c) the residual sum of squares.

Single-Factor Analysis. To demonstrate the 10-step procedure we have just described, we want you to use the data from table 1–17 and compute an F value for the thermometers. To make the data easier to handle, you code it. You can use any value that will give you convenient figures to work with. Generally, where you subtract a coding value, you do not have to uncode after you complete your calculations. In this example, 172.0, which is an approximate average, is subtracted from each of the readings. In some cases, this gives you negative numbers, but since you are going to square all of these numbers anyway, the minus signs will all disappear in your computations. The coded data is set down in table 1–19. We suggest that you check each value against its corresponding value in table 1–17 and also verify the correctness of the totals.

There are 12 separate values (X) and 3 rows; thus, N = 12 and r = 3. You can also see that T_j = 4.5, 2.0, −0.5, and 1.0. Moreover, T = 7.0. Now you are ready to obtain values for Q_t, Q_c, and Q_o.

The equation $\Sigma X^2 - \frac{T^2}{N}$ tells you that you must square each individual and find the sum; thus, 1.0 + 4.0 + 2.25 + 0.0 + 1.0 + 1.0 + 1.0 + 0.25 + 1.0 + 0.25 + 2.25 + 1 = 15.0. Then you must square the grand total, T, and divide it by N to get the correction factor; thus, 49/12 = 4.08. Substituting the values gives you

$$Q_T = \Sigma X^2 - \frac{T^2}{N} = 15.0 - 4.08 = 10.92.$$

To solve for Q_c, you must square and sum the column totals, divide the sum (ΣT_j) by the number of rows (r), and subtract the correction factor $\left(\frac{T^2}{N}\right)$

TABLE 1-18

VARIANCE RATIO, 5 PERCENT (F SCORE)

233-88

n_2 \ n_1	1	2	3	4	5	6	8	12	24	∞
1	161·4	199·5	215·7	224·6	230·2	234·0	238·9	243·9	249·0	254·3
2	18·51	19·00	19·16	19·25	19·30	19·33	19·37	19·41	19·45	19·50
3	10·13	9·55	9·28	9·12	9·01	8·94	8·84	8·74	8·64	8·53
4	7·71	6·94	6·59	6·39	6·26	6·16	6·04	5·91	5·77	5·63
5	6·61	5·79	5·41	5·19	5·05	4·95	4·82	4·68	4·53	4·36
6	5·99	5·14	4·76	4·53	4·39	4·28	4·15	4·00	3·84	3·67
7	5·59	4·74	4·35	4·12	3·97	3·87	3·73	3·57	3·41	3·23
8	5·32	4·46	4·07	3·84	3·69	3·58	3·44	3·28	3·12	2·93
9	5·12	4·26	3·86	3·63	3·48	3·37	3·23	3·07	2·90	2·71
10	4·96	4·10	3·71	3·48	3·33	3·22	3·07	2·91	2·74	2·54
11	4·84	3·98	3·59	3·36	3·20	3·09	2·95	2·79	2·61	2·40
12	4·75	3·88	3·49	3·26	3·11	3·00	2·85	2·69	2·50	2·30
13	4·67	3·80	3·41	3·18	3·02	2·92	2·77	2·60	2·42	2·21
14	4·60	3·74	3·34	3·11	2·96	2·85	2·70	2·53	2·35	2·13
15	4·54	3·68	3·29	3·06	2·90	2·79	2·64	2·48	2·29	2·07
16	4·49	3·63	3·24	3·01	2·85	2·74	2·59	2·42	2·24	2·01
17	4·45	3·59	3·20	2·96	2·81	2·70	2·55	2·38	2·19	1·96
18	4·41	3·55	3·16	2·93	2·77	2·66	2·51	2·34	2·15	1·92
19	4·38	3·52	3·13	2·90	2·74	2·63	2·48	2·31	2·11	1·88
20	4·35	3·49	3·10	2·87	2·71	2·60	2·45	2·28	2·08	1·84
21	4·32	3·47	3·07	2·84	2·68	2·57	2·42	2·25	2·05	1·81
22	4·30	3·44	3·05	2·82	2·66	2·55	2·40	2·23	2·03	1·78
23	4·28	3·42	3·03	2·80	2·64	2·53	2·38	2·20	2·00	1·76
24	4·26	3·40	3·01	2·78	2·62	2·51	2·36	2·18	1·98	1·73
25	4·24	3·38	2·99	2·76	2·60	2·49	2·34	2·16	1·96	1·71
26	4·22	3·37	2·98	2·74	2·59	2·47	2·32	2·15	1·95	1·69
27	4·21	3·35	2·96	2·73	2·57	2·46	2·30	2·13	1·93	1·67
28	4·20	3·34	2·95	2·71	2·56	2·44	2·29	2·12	1·91	1·65
29	4·18	3·33	2·93	2·70	2·54	2·43	2·28	2·10	1·90	1·64
30	4·17	3·32	2·92	2·69	2·53	2·42	2·27	2·09	1·89	1·62
40	4·08	3·23	2·84	2·61	2·45	2·34	2·18	2·00	1·79	1·51
60	4·00	3·15	2·76	2·52	2·37	2·25	2·10	1·92	1·70	1·39
120	3·92	3·07	2·68	2·45	2·29	2·17	2·02	1·83	1·61	1·25
∞	3·84	2·99	2·60	2·37	2·21	2·10	1·94	1·75	1·52	1·00

Lower 5 per cent. points are found by interchange of n_1 and n_2, *i.e.* n_1 must always correspond with the greater mean square.

TABLE 1-19
MELTING POINTS OF HYDROQUINONE (CODED - 172.0)

233-89

	THERMOMETERS				
READINGS	A	B	C	D	GRAND TOTAL
	1.0	0.0	-1.0	0.5	
	2.0	1.0	-0.5	1.5	
	1.5	1.0	1.0	-1.0	
Totals	4.5	2.0	-0.5	1.0	7.0

Thus,

$$Q_c = \frac{\Sigma T_j^2}{r} - \frac{T^2}{N}$$

$$= 4.5^2 + 2.0^2 - 0.5^2 + 1.0^2 - \frac{49}{12} = \frac{25.50}{3} - 4.08$$

$$= 4.42$$

The residual sum of squares is

$$Q_o = Q_T - Q_c = 10.92 - 4.42 = 6.50$$

Now, all you need is to determine the degrees of freedom to complete your calculations and compile an ANOVA table.

For convenience, the ANOVA table illustrated in figure 1-28 is repeated as table 1-20 but with the values filled in. The degrees of freedom for thermometers (columns) is c − 1 = 4 − 1 = 3, the degrees of freedom for the total is N − 1 = 12 − 1 = 11, and the degrees of freedom for residual is the difference between the two: 11 − 3 = 8. These values are placed in their appropriate places in the table. The mean square is the sum of squares divided by the degrees of freedom. For thermometers, it is 4.42/3 = 1.47, and for residual, it is 6.50/8 = 0.81. These values are placed in the spaces provided for them in the table, and all that remains is for you to compute F and compare it with the book F.

The ratio, mean square for thermometers over the mean square for residual, is

$$F = 1.47/0.81 = 1.81$$

Thus, 1.81 is the calculated value for F. Now turn to table 1-18, find the degrees of freedom for the numerator (3) at the top of the page, and the degrees of freedom for the denominator (8) at the left of the page. Then trace down the column and across the row to the point of intersection. The value at this point is 4.07 and is reported

$$F3, 8, 0.05 = 4.07$$

Since this value is larger than your calculated value, you accept the null hypothesis that $v_j = 0$, and say that there is no significant difference in the accuracy of the four thermometers tested.

Exercises (A49):

1. The formula $\frac{T^2}{N}$ appears frequently in analysis of variance formulas. What does it tell you to do, and what does it give you?

2. What is meant by the symbol T_j?

3. How do you compute the sum of the squares for columns?

4. How do you compute the total sum of squares?

5. How do you compute the residual sum of the squares?

A50. Contrast a 2-factor analysis of variance with that of a single-factor analysis and specify how to compute (a) the residual sum of the squares and (b) the degrees of freedom for Q_T, Q_c, Q_r, and Q_o for a 2-factor analysis.

Two Factor, Nonreplicated Analysis. We have just completed the procedure for the simplest and least informative analysis of variance. Now you are ready to move on to tests that will give you more information about the variables you are testing. In the previous tests, all variables except thermometers were ignored. If you think about it, you must realize that differences in readings could result from the different ways technicians might read thermometers. If you consider the second variable, you must include the technicians and test for their effect.

TABLE 1-20
COMPLETED ANOVA TABLE

233-90

Source	Sum of Squares SS	Degrees of Freedom df	Mean Square MS
Thermometers	4.42	3	1.47
Residual	6.50	8	0.81
Total	10.92	11	

TABLE 1-21

MELTING POINTS OF HYDROQUINONE, 2-FACTOR TEST

233-91

THERM- TECH	A	B	C	D	T_i
I	1.0	0.0	-1.0	0.5	0.5
II	2.0	1.0	-0.5	1.5	4.0
III	1.5	1.0	1.0	-1.0	2.5
T_j	4.5	2.0	-0.5	1.0	GRAND TOTAL 7.0

Your data will be presented in the form shown in table 1-21. Notice that the rows indicate three different technicians (I, II, and III) and also show the row totals (T_i).

Your objective is twofold. You want to know: (1) are the thermometers alike and (2) are the technicians reading them in the same way. Your model is also expanded to include the "technician effects" and can be shown as:

$$X_{ij} = \mu + v_j + \sigma i + \epsilon ij$$

σi = technician effects

Both variables must also be included in your statement of hypotheses. Actually, you have two null hypotheses and two alternative hypotheses:

$$H_{01} : v_j = 0 \; H_{1_1} = v_j > 0$$

and

$$H_{02} : \sigma i = 0 \; H_{1_2} = \sigma i > 0$$

You must also add the following terms to the nomenclature: T_i = total for the i^{th} row, and Q_r = sum of squares for rows, shown symbolically by the equation:

$$Q_r = \frac{\Sigma T^2_i}{c} - \frac{T_2}{N}$$

or

$$Q_r = \frac{1}{c} \Sigma T_i{}^2 - \frac{T^2}{N}$$

You should recognize that you are (1) squaring the row totals, (2) summing them, (3) dividing by the number of columns, and (4) subtracting the correction factor. To illustrate, substitute values and complete the equation.

Thus

$$Qr = \frac{\Sigma T_i{}^2}{c} - \frac{T^2}{N} = \frac{0.5^2 + 4.0^2 + 2.5^2}{4} - \frac{7.0^2}{12}$$

$$= \frac{22.5}{4} - \frac{49}{12} = 5.63 - 4.08 = 1.55$$

You can now add Q_r = 1.55 to your calculations.

The sum of squares for residual is what is left after you subtract all other sums of squares from the total sum of squares. In this case, the equation is:

$$Q_e = Q_T - (Q_c + Q_r) = 10.92 - (4.42 + 1.55) = 4.95$$

This value, also, can be added to your calculations.

You follow the established procedure for obtaining degrees of freedom and get:

df for Q_T = N − 1 = 12 − 1 = 11
df for Q_c = c − 1 = 4 − 1 = 3
df for Q_r = r − 1 = 3 − 1 = 2
df for Q_e = (c − 1)(r − 1) = (3)(2) = 6, or
df for Q_e = (N − 1) − (c − 1 + r − 1) = 11 − 5 = 6

Notice that you have two alternative methods for obtaining df for Q_e. Use whichever method is more convenient for you.

Your next step is to organize your calculations and prepare the ANOVA table. In the beginning, it is good practice to set down the calculated values in the following format:

SS for Q_T = 10.92
SS for Q_c = 4.42
SS for Q_r = 1.55
SS for Q_e = 4.95
df for Q_T = 11
df for Q_c = 3
df for Q_r = 2
df for Q_e = 6
MS for columns = 4.42/3 = 1.47
MS for rows = 0.42/2 = 0.21
MS for residual = 6.08/6 = 1.01

However, as you become experienced, you might save time by completing your ANOVA table as you perform your calculations. In either case, your ANOVA table for this test will be as shown in table 1-22.

To complete the F test, your calculated variance for columns (thermometers) is

1.47/1.01 = 1.46

The book value is

F3, 6, .05 = 4.76

TABLE 1-22

ANOVA TABLE FOR 2-FACTOR ANALYSIS

233-92

Source	Sum of Squares SS	Degrees of Freedom df	Mean Square MS
Thermometers	4.42	3	1.47
Technicians	0.42	2	0.21
Residual	6.08	6	1.01
Total	10.92	11	

TABLE 1-23
MELTING POINTS OF HYDROQUINONE, ALTERNATE VALUES

233-93

	A	B	C	D	T_j
I	1.0	0.0	-1.0	-1.0	-1.0
II	1.5	1.0	1.0	0.5	4.0
III	1.0	1.0	-0.5	1.5	4.0
Total	4.5	2.0	-0.5	1.0	7.0

The calculated variance for rows (technicians) is

1.01/0.21 = 4.81

The book value is

F2, 6, .05 = 5.14

Now you can conclude that since both calculated values are lower than their respective book values, you should accept both null hypotheses.

To demonstrate that a two-factor analysis is more discriminating than a single-factor analysis, let us assume that the technicians' readings were somewhat different. In table 1-23 we have taken the same data but have attributed some of the readings to different technicians.

NOTE: At this point, let us caution you that in practice you must not juggle the data in this manner. While the situations we create here are entirely possible, we have taken liberty with the data only to demonstrate a point. Notice that the column totals and the grand totals are still the same, but the row totals are changed. If you used only single-factor tests, you would not be aware of this nor would you know if such a difference would affect your conclusions. Therefore, run a test and see what happens.

Applying the preceding steps and calculations should give you an ANOVA table such as table 1-24.

Completing the calculations gives you the following results:

For columns (thermometers)

$$F = 1.47/0.39 = 3.77$$

For book F

$$F_{3, 6, 0.05} = 4.76$$

For rows (technicians)

$$F = 2.09/0.39 = 5.36$$

For book F

$$F_{2, 6, 0.05} = 5.14$$

Now you see that you must accept H_{o1}; $v_j = 0$ and reject H_{o2}: $\sigma i = 0$. If the technicians had read the thermometers in this way, a significant variance would have existed, and a single-factor test would not have indicated it. However, if all of the readings had been made by the same technician, there would have been only one variable, and the single-factor test would have been sufficient. Whenever you have more than one variable, you must test for each.

Exercises (A50):

1. A two-factor analysis of variance differs from a single-factor analysis of variance in what ways?

2. How do you compute the residual sum of the squares for a two-factor analysis of variance?

TABLE 1-24
ANOVA TABLE FOR DATA FROM TABLE 1-23

233-94

Source	Sum of Squares SS	Degrees of Freedom df	Mean Square MS
Thermometers	4.42	3	1.47
Technicians	4.17	2	2.09
Residual	2.33	6	0.39
Totals	10.92	11	

3. In a two-factor test, how do you compute the degrees of freedom for Q_T, Q_c, Q_r, and Q_o?

A51. Define "pooling" and state when to pool.

Pooling. In the two-factor test just completed, where there is a significant variance due to technicians but none due to thermometers, you might decide to pool the thermometer sum of squares with the original error (residual) sum of squares if you feel that the thermometer variation is due solely to chance. This gives you 4.42 + 2.33 = 6.75 for the pooled sum of squares, and 3 + 6 = 9 for the pooled degrees of freedom. The new error mean square for the pooled values is 6.75/9 = 0.75. Now, your book F is F9, 2, 0.05 = 4.26 instead of F2, 6, 0.05 = 5.14, and you have a more precise test. This might suggest that you should always pool in cases like this, but suppose that the thermometer variation is not due entirely to chance. Suppose that there is an assignable cause too slight to be detected by your test. In such a case, pooling the sums of squares would tend to increase the error mean square and the test would be less sensitive.

There is no absolutely sure way for you to decide when it is best to pool. If you adopt the policy of never pooling, you run the risk of sometimes getting a less precise test than you should. On the other hand, if you always pool, the basis for your tests becomes more complex and the chance of wrongly accepting or rejecting the null hypothesis becomes greater. If you feel that you should pool sometimes and not others, you should form some basis for making the decision. Some statisticians say: "If the degrees of freedom for the original (residual) error mean square are 6 or more, do not pool. If the degrees of freedom for the original error mean square are less than 6, pool if the variance ratio for the sums of squares to be pooled is not greater than 2."

Exercises (A51):

1. What is meant by the term "pooling," and why should pooling be done?

2. Is there some guide to help a technician decide when to pool and when not to? Specify.

A52. Define a replicated analysis of variance and state when to replicate an analysis of variance.

Two-Factor Replicated Analysis of Variance. In many instances, for the sake of increased precision and accuracy, experiments are replicated; that is, conducted more than once. For example, suppose that the technicians who provided the data for table 1-23, instead of each making one reading on each thermometer, made two. The data obtained from their replicated readings would then be as given in table 1-25.

You can see that now, since there are more data to consider, the number of variables increases. In fact, adding variables might produce effects that are greater than the sum of the effects produced by each variable. In other words, there might be interactions between variables that

TABLE 1-25

MELTING POINTS OF HYDROQUINONE, REPLICATE READINGS

233-95

THERMOMETERS

		A		B		C		D		Totals
TECHNICIANS	I	1.0 1.0	2.0	0.0 1.0	1.0	−1.0 0.0	−1.0	−1.0 0.0	−1.0	1.0
	II	1.5 1.0	2.5	1.0 1.5	2.5	1.0 1.0	2.0	0.5 1.0	1.5	8.5
	III	2.0 1.5	3.5	1.0 1.5	2.5	−0.5 0.5	0.0	1.5 1.5	3.0	9.0
	Totals		8.0		6.0		1.0		3.5	GRAND TOTAL 18.5

produce unexpected effects. If your testing is to be of benefit to you, you must analyze for this interaction as well as for the ordinary variables. Therefore, when you state your objectives, you ask: (1) Is there a significant difference between the thermometers? (2) Is there a significant difference between the technicians? (3) Is there any significant interaction between the two? Your model now takes the following form:

$$X_{ij}K = \mu + v_j + \sigma i + C_{ij} + \epsilon_{ij}k$$

where

K = the number of replicated readings in each box

and

C_{ij} = the effect of interaction

You have three null hypotheses, namely,

v_i = 0 (thermometers)
σ_i = 0 (technicians)
C_{ij} = 0 (thermometer-technician interaction)

You must also add the following symbols to your nomenclature:

m = number of replications per cell
T_{ij} = total in the cell at row i, column j

For Q_I

$$Q_I = \frac{\Sigma T^2_{ij}}{m} - \frac{T^2}{N} - (Q_c + Q_r)$$

$$= \frac{(2.0^2 + 1.0^2 + -1.0^2 + -1.0^2 + 2.5^2 + 2.5^2 + 2.0^2 + 1.5^2 + 3.5^2 + 2.5^2 + 0.0^2 + 3.0^2)}{2}$$

$$- \frac{18.5^2}{24} - (5.021 - 4.615) = 26.625 - 14.260 - 5.021 - 4.615 = 2.729$$

For Q_e:

$$Q^{\circ} = Q_T - (Q_c + Q_r + Q_I)$$

$$= 14.990 - (4.615 + 5.021 + 2.729)$$

$$= 14.990 - 12.365 = 2.625$$

Q_I = interaction, as given by the equations:

$$Q_I = \left(\frac{\Sigma T^2_{ij}}{m}\right) - \frac{T^2}{N} - (Q_r + Q_c)$$

or

$$Q_I = \frac{1}{m}\Sigma T^2_{ij} - \frac{T^2}{N} - (Q_r + Q_c)$$

Calculate values for your analysis of variance as follows:

For Q_T:

$$Q_T = \Sigma X^2 - \frac{T^2}{N}$$

Square and sum each individual reading. In this analysis, there are 24 readings, and the equation becomes:

For Q_T:

$$Q_T = (1.0^2 + 1.0^2 + 1.0^2 + -1.0^2 + -1.0^2 + 1.5^2$$
$$+ 1.0^2 + 1.0^2 + 1.5^2 + 1.0^2 + 1.0^2 + 0.5^2$$
$$+ 1.0^2 + 2.0^2 + 1.5^2 + 1.0^2 + 1.5^2 + -0.5^2$$
$$+ 0.5^2 + 1.5^2 + 1.5^2) - \frac{18.5^2}{24} = 29.25 - 14.26$$
$$= 14.99$$

For Q_c:

$$Q_c = \frac{\Sigma T^2_i}{mr} - \frac{T^2}{N}$$

$$= \frac{(8.0^2 + 6.0^2 + 1.0^2 + 3.5^2)}{6} - \frac{18.5^2}{24}$$

$$= 18.875 - 14.260 = 4.615$$

For Q_r:

$$Q_r = \frac{\Sigma T^2_i}{mc} - \frac{T^2}{N}$$

$$= \frac{(1.0^2 + 8.5^2 + 9.0^2)}{8} - \frac{18.5^2}{24}$$

$$= 19.281 - 14.260 = 5.021$$

where

$$m = 2 \; r = 3 \text{ and } c = 4$$

Compute the degrees of freedom as follows:

For Q_T:

$$N - 1 = 24 - 1 = 23$$

For Q_c:

$$c - 1 = 4 - 1 = 3$$

For Q_r:

$$r - 1 = 3 - 1 = 2$$

TABLE 1-26

ANOVA TABLE FOR 2-FACTOR, REPLICATED ANALYSIS

233-96

Source	Sum of Squares SS	df	MS
Thermometers	4.615	3	1.54
Technicians	5.021	2	2.51
Interaction	2.729	6	0.45
Residual	2.625	12	0.22
Totals	14.990	23	

For Q_I:

$$(c-1)(r-1) = 3 \times 2 = 6$$

For Q_o:

$$rc(m-1) = 3 \times 4 \times (2-1) = 12$$

Prepare your ANOVA table to include interaction. It should resemble table 1-26.

Compute your F values as follows:

For thermometers,

$$\frac{MS_c}{MS_{resid}} = \frac{1.54}{0.22} = 7.00.$$

The book table gives F3, 12, 0.05 = 3.49. Therefore, you reject the null hypothesis.

For technicians,

$$\frac{MS_r}{MS_{resid}} = \frac{2.51}{0.22} = 11.41.$$

The book F is F2, 12, 0.05 = 3.89. Therefore, you reject the hypothesis.

For interaction,

$$\frac{MS_I}{MS_{resid}} = \frac{0.45}{0.22} = 2.05.$$

The book F is F6, 12, 0.05 = 3.00. Therefore, you accept the null hypothesis.

Now the question arises, "should I pool?" You see that the degree of freedom for your sum of squares for residual (original error) is 6. The variance ratio of the sums of squares to be pooled (interaction and residual) is $\frac{12}{6} = 2$. Therefore, you experiment is within the guideline that has been set, and it might be wise to pool. The mean square for the pooled sums of squares is:

$$\frac{2.729 + 2.625}{6 + 12} = 0.30$$

and you can recompute your calculated F's using this value.

For thermometers: $\frac{1.54}{0.30} = 5.1$

For book F: F3, 18, 0.05 = 3.18

For technicians: $\frac{2.51}{0.30} = 8.4$

For book F: F2, 18, 0.05 = 3.57

Since you find that both are greater than their respective book values, you still reject the null hypotheses. Your test tells you that there is a significant difference in the thermometers and in the way technicians read them.

Exercises (A52):

1. What is a replicated analysis of variance?

2. When should you replicate an analysis of variance?

A53. Specify the kind of analysis needed for three variables. Treat the data in a three-factor analysis of variance. Specify how to compute the sum of squares for interaction in a three-factor analysis. Given data on three variables, obtain the sums of squares for (a) A and B ANOVA table, (b) B and C ANOVA table, and (c) for A and C ANOVA table. Specify how you compute the residual sum of squares for the grand ANOVA of a three-factor analysis, and how to conduct the F test in a three-factor analysis of variance.

Three-Factor Analysis of Variance. Very often in precision imagery operations, you will want to analyze the effect of three variables. For example, you may have

TABLE 1-27

TEST STRIPS (SENSITOMETERS, DENSITOMETERS, AND DEVELOPING TIMES)

233-97

	S_1		S_2		S_3	
	D_A	D_B	D_A	D_B	D_A	D_B
T_1	0.42	0.38	0.79	0.51	0.60	0.66
T_2	1.11	1.10	1.41	1.35	1.48	1.57
T_3	1.49	1.61	1.86	1.88	2.12	2.16
T_4	1.75	1.85	2.09	2.08	2.28	2.41
T_5	1.81	1.90	2.28	2.18	2.38	2.45

several sensitometers and several densitometers upon which control densities are produced and read. You would want to know the effect of the two different types of equipment upon the densities produced in a film, and you would want to establish a developing time to give you the optimum precision in your developed image. Thus, you would have three factors to consider: (1) the sensitometers, (2) the densitometers, and (3) the developing time. To illustrate, let us take a typical case. Assume that you have three sensitometers designated S_1, S_2, and S_3, and two densitometers designated D_A and D_B. You plan to process test exposures for five developing times designated T_1, T_2, T_3, T_4, and T_5. You would arrange your data as shown in table 1-27.

In this analysis, you data consist of densities read (on each densitometer) from the 11th step of each of the test strips exposed on each of the sensitometers. This means that 10 strips must be exposed on each sensitometer and developed six at a time (two from each sensitometer) for five different times. Then 15 strips (one each for five different times and three different sensitometers) are read on each densitometer to determine the 11th step density. These values are entered in the appropriate spaces in the table.

Your objectives are to determine if there is (1) a significant difference in the sensitometers, (2) a significant difference in densitometers, (3) a significant difference in developing times, and (4) a significant difference caused by interaction between any of these factors.

In carrying out a 3-factor analysis, you must make three, separate, two-factor tables giving the sums of the row and column values of paired factors as shown in table 1-28. This is called summing over, and the tables are called sum-over tables (used to compare sums of squares of variables). In table 1-28, A, the three values, 0.41, 0.79, and 0.60, for the readings from densitometer D_A at time T_1 have been added and their sum, 1.80, placed in the appropriate space in the table. This process has been repeated for D_BT_1, D_AT_2, D_BT_2, ..., D_AT_5, D_BT_5. The same procedure has been followed with the S and D values to complete table 1-28, B, and with the S and T values to complete table 1-28, C.

Your next step is to construct three, two-factor ANOVA tables (table 1–29).

To obtain the S sum of squares for the S and T ANOVA (table 1-29, A), you take the column totals from the sum-over D table (table 1-28, C), square them, add them together, divide their sum by the total number of cases under each S, and then subtract the correction factor, $\frac{T^2}{N}$, as follows:

$$\text{SS for S} = \frac{13.42^2 + 16.43^2 + 18.11^2}{10} - \frac{47.96^2}{30}$$

$$= \frac{180.10 + 269.94 + 327.97}{10} - \frac{2300.16}{30}$$

$$= \frac{778.01}{10} + \frac{2300.16}{30} = 77.801 - 76.672$$

$$= 1.129$$

Similarly, you calculate the sum of squares for T from the row totals in the sum-over D table.

TABLE 1-28
SUM-OVER TABLES

233-98

A. Sum over S, (T and D Values)

	D_A	D_B	Σ
T_1	1.81	1.55	3.36
T_2	4.00	4.02	8.02
T_3	5.47	5.65	11.12
T_4	6.12	6.34	12.46
T_5	6.47	6.53	13.00
Σ	23.87	24.09	47.96

B. Sum over T (S and D Values)

	D_A	D_B	Σ
S_1	6.58	6.84	13.42
S_2	8.43	8.00	16.43
S_3	8.86	9.25	18.11
Σ	23.87	24.09	47.96

C. Sum over D (S and T Values)

	S_1	S_2	S_3	Σ
T_1	0.80	1.30	1.26	3.36
T_2	2.21	2.76	3.05	8.02
T_3	3.10	3.74	4.28	11.12
T_4	3.60	4.17	4.69	12.46
T_5	3.71	4.46	4.83	13.00
Σ	13.42	16.43	18.11	47.96

Thus

$$\text{SS for D} = \frac{3.36^2 + 8.02^2 + 11.12^2 + 12.46^2 + 13.00^2}{6} - \frac{47.96^2}{30}$$

$$= \frac{11.29 + 64.32 + 123.65 + 155.25 + 169.00}{6} - \frac{2300.16}{30}$$

$$= \frac{523.510}{6} - \frac{2300.16}{30} = 87.2517 - 76.672 = 10.579$$

TABLE 1-29

2-FACTOR ANOVA TABLES FOR 3-FACTOR ANALYSIS OF VARIANCE

233-99

A. S and T ANOVA

Source	SS	df	MS
S	1.129	2	0.565
T	10.579	4	2.645
S and T (Interaction)	0.108	8	0.0135
Totals	11.816	14	

B. D and T ANOVA

Source	SS	df	MS
D	0.00166	1	0.00166
T	10.58100	4	2.64500
S and T (Interaction)	0.02310	4	0.005775
Totals	10.60576	9	

C. D and S ANOVA

Source	SS	df	MS
D	0.0017	1	0.0017
S	1.1290	2	0.5645
D and S (Interaction)	0.0391	2	0.0196
Totals	1.1698	5	

You see that you divide the sum of the squared totals for T by 6, since there are 6 cases for each value of T.

Find the sum of squares for the S and T interaction by (1) squaring each individual value in the sum-over D table, (2) adding the squares, (3) dividing their sum by the number of units of information in each cell (two in this table), (4) subtracting the correction factor, and finally (5) subtracting the sum of squares for S plus the sum of squares for T.

Thus

$$\text{SS for S and T} = \frac{\Sigma(\text{S and T})^2}{\text{units per cell}} - \frac{T^2}{N} - (SS_S + SS_T)$$

$$0.80^2 + 1.30^2 + 1.26^2 + 2.21^2 + 2.76^2$$

$$+ 3.05^2 + 3.10^2 + 3.74^2 + 4.28^2 + 3.60^2 - \frac{47.96^2}{30} - (1.129 + 10.581)$$

$$= + \frac{4.17^2 + 4.69^2 + 3.71^2 + 4.46^2 + 4.83^2}{2}$$

$$+ 0.6400 + 1.6900 + 1.5876 + 4.8841 + 7.6176$$

$$+ 9.3025 + 9.6100 + 13.9876 + 18.3184 + 12.9600 - \frac{2300.16}{30} - 11.710$$

$$= + \frac{17.3889 + 21.9961 + 13.7641 + 19.8916 + 23.3289}{2}$$

$$= \frac{176.9808}{2} - 76.6720 - 11.70 = 88.4904 - 76.6721 - 11.710$$

$$= 0.1083 \text{ (rounded off 0.108)}$$

Place this value in your S and T ANOVA table, and bring down the total sum of squares. Using the procedures you have already learned, compute the degrees of freedom and the mean squares and complete the table.

Compute the data for your D and T ANOVA (table 1-29, B) in the same manner. The sum of squares for D is calculated from the sum over T or the sum over S tables as follows:

$$\text{SS for D and T} = \frac{\Sigma(\text{D and T})^2}{\text{S units}} - \frac{T^2}{N}\ (SS_D + SS_T)$$

$$= \frac{261.8342}{3} - \frac{47.96^2}{30}\ (0.00166 + 10.581)$$

$$= 87.277806 - 76.672000 - 10.58266 = 0.0231$$

where S units = number of sensitometers.

Calculate the df and MS in the usual manner, and complete the D and T ANOVA.

To compute the D and S ANOVA (table 1-29, C), all that you need to do is to find the sum of squares, df and MS for interaction, and bring down the total sum of squares. You have already computed the other values. You simply insert them in the table where they belong. Calculate the D and S interaction sum of squares using the equation:

$$\text{SS for D and S} = \frac{\Sigma(\text{D and S})^2}{\text{T units}} - \frac{T^2}{N} - (SS_D + SS_S)$$

$$= \frac{389.2090}{5} - \frac{47.96^2}{30} - (0.00166 + 1.129)$$

$$= 77.8418 - 76.6720 - 1.13066$$

$$= 0.0391$$

where T units = number of developing times.

Now you must gather all of your data into one table called the grand ANOVA, as shown in table 1-30. Compute the sum of squares for residual by adding up the sums of squares for S, D, T, for S and D, for S and T, for D and T,

TABLE 1-30

GRAND ANOVA TABLE FOR 3-FACTOR ANALYSIS

233-100

Source	SS	df	MS
S	1.12900	2	0.56450
D	0.00166	1	0.00166
T	10.58100	4	2.64525
S and D	0.03910	2	0.01955
S and T	0.10800	8	0.0135
D and T	0.02340	4	0.00585
Residual	0.06024	8	0.01353
Totals	11.94210	29	

and then subtracting their sum from the sum of all of the squares of your original data (table 1-27) minus the correction factor. Do this according to the equation,

$$SS_{resid} = (\Sigma X^2 - \frac{T^2}{N}) - \Sigma\ SS$$

$$= 88.5646 - 76.720 - 11.78436 = 0.06024$$

$$\text{SS for D} = \frac{23.87^2 + 24.09^2}{15} - \frac{47.96^2}{30}$$

$$= \frac{569.7769 + 580.3281}{15} - \frac{2300.16}{30}$$

$$= \frac{1150.1050}{15} - \frac{2300.16}{30}$$

$$= 76.67366 - 76.67200 = 0.00166$$

Compute the D and T interaction from the equation:

$$\text{SS for D and T} = \frac{\Sigma(\text{D and T})^2}{\text{S units}} - \frac{T^2}{N}\ (SS_D + SS_T)$$

$$= \frac{261.8342}{3} - \frac{47.96^2}{30}\ (0.00166 + 10.581)$$

$$= 87.278066 - 76.672053 - 10.58266 = 0.0234$$

Enter this value in your grand ANOVA and bring down the total. Compute degrees of freedom on the basis of N - 1 and enter them in the table. Then, applying the equation $MS = \frac{SS}{df}$, compute the mean squares and complete the table.

Finally, find the F value of each variable by calculating the ratio of the MS of each to the MS of residual and compare the calculated F's to the book F's as follows:

Calculated F	*Book F*	
S: $\frac{0.5645}{0.01353} = 41.722$	F 2, 8, 0.05	4.46
D: $\frac{0.00166}{0.01353} = 0.12269$	F 1, 8, 0.05	5.32
T: $\frac{2.64525}{0.01353} = 195.51$	F 4, 8, 0.05	3.84
S and D: $\frac{0.01955}{0.01353} = 1.445$	F 2, 8, 0.05	4.46
S and T: $\frac{0.01350}{0.01353} = 0.9978$	F 8, 8, 0.05	3.44
D and T: $\frac{0.00585}{0.01353} = 0.4324$	F 4, 8, 0.05	3.84

The comparison of calculated F's and book F's shows a significant variation owing to developing time. If you were applying this analysis to a production facility, you would take steps to bring your sensitometers into closer agreement and you would standardize development times to obtain optimum quality. Additional analysis might have to be run before you would be completely satisfied.

Exercises (A53):

1. What kind of analysis must you make when you have three variables to consider?

2. How do you treat the data in a three-factor analysis of variance?

3. How do you compute the sum of squares for interaction in a three-factor analysis?

4. Assuming that you have three variables—A, B, and C—and you prepared the required three sum-over tables, how do you obtain the sums of squares for the A and B ANOVA table? For the B and C ANOVA table? For the A and C ANOVA table?

5. How do you compute the residual sum of squares for the grand ANOVA of a three-factor analysis?

6. How do you conduct the F test in a 3-factor analysis of variance?

1-7. Design of Experiments

You have been learning how to use certain statistical tools for evaluating the results of more or less routine experiments. The procedure to be followed in each case was given to you. Now we want to discuss, briefly, the ways in which these experiments are developed. Moreover, we want to introduce you to suggested formats that, after you become proficient in statistical analyses, you may use to design experiments to fit your own needs. Before we begin, we want to point out that this section can do little more than enumerate the elements of experimental design. Its purpose is to provide you with background knowledge that should increase your understanding of the routine tests you will conduct, and it should give you a starting place from which to pursue further study on the subject.

A54. Cite the three prerequisites for a designed experiment.

Prerequisites. When we speak of a "designed experiment," we have certain definite procedures in mind. We define a designed experiment as one planned in such a way that the results obtained will answer the specific questions that prompted us to make the experiment. Before designing an experiment, you should establish, in writing, the information set forth in the following three prerequisites:

a. State the objective of the experiment. Questions asked in the objectives should not be vague. They should be specific enough to warrant an answer, yet broad enough to allow you to use the results to make inferences about the population. Classify major and minor points to insure that you confine your experiment to the steps necessary to satisfy your objective.

b. Describe the experiment, outlining procedures, materials, methods of randomization, and all other pertinent facts. This includes (1) listing all factors that might contribute variability, (2) choosing levels for factors to be studied, (3) providing for possible interaction, and (4) adopting a randomizing procedure to eliminate bias which might be caused by any of the factors not being studied.

c. Outline the method to be used to analyze the results of the experiment. Determine the size of experiment needed to provide the desired sensitivity, bearing in mind that replication as well as the type of design will affect the number of tests required.

If you intend that the results of an experiment represent the nature of some population, you must be sure that you conduct your experiment on a sample that is representative of that population. Randomize all factors (other than those under study or those deliberately set at some standard level) to eliminate sources of bias. Since you will have designated the method of analysis, you can treat the results of the experiment according to prescribed rules with specified probabilities of risks of error. The results obtained from a designed experiment may readily be compared with, or combined with, the results from other experiments and can give you a measure of random error.

Exercises (A54):

1. What are the three prerequisites you should meet before designing an experiment?

A55. Name two sources of experimental error that exist in statistical experiments and specify what you try to accomplish when setting out to design a statistical experiment.

Planning Designed Experiments. In every statistical experiment there exists an experimental error that originates in two sources: one is the lack of uniformity of the material; the other is the inherent variability in the experimental technique. This is the basic error that applies to a single elementary experiment, and nothing can be done statistically to change it. However, the basic error can be reduced by improving (1) the material, (2) the experimental technique, or (3) both.

As you have seen in your study of analysis of variance experiments, a complete experiment usually consists of a series or combination of elementary experiments whose results are in the form of a mean value, or a set of mean values. When designing and conducting an experiment, your goal is to test hypotheses pertaining to the universe or population mean values, and perhaps to estimate the means and the various components of variance. There are several possible ways of doing this. However, you will often find that one design excels for your particular purposes. This design is the one you should use. The selection of the "one" best method is not easy. Much experience is necessary before you can design an experiment and be confident that it will give you all the information you want. It is the purpose of this text to start you in the right direction to acquire this experience. Perhaps we should start by giving you a checklist that applies generally to designing all experiments.

Exercises (A55):

1. What are two sources of experimental error that exist in statistical experiments?

2. When setting out to design a statistical experiment, what do you try to accomplish?

A56. Cite the preparatory step needed to aid in designing experiments.

Checklist for Preparing Designed Experiments. No matter what type of statistical experiment you wish to design, you will benefit from the use of the following checklist.

a. State the problem clearly.

(1) Identify the new (or critical) problem area.

(2) Outline all specific problems within current limitations.

(3) Determine the exact scope of the test experiment.

(4) Determine the relationship of the problem to the whole program.

b. Accumulate all available background information.

(1) Investigate all available sources for data.

(2) Select and tabulate the data pertinent to the experiment.

c. Design the experiment.

(1) Confer with all parties involved in the operation.

(a) State the propositions to be proved.

(b) Decide on the magnitude of differences considered to be significant.

(c) Outline any possible alternative outcomes.

(d) Select the factors to be studied.

(e) Decide on the practical range of these factors and the specific levels at which the tests will be made.

(f) Decide what end measurements are to be made.

(g) Consider the effect of sampling variability and the effect of the preciseness of test methods.

(h) Consider any possible interactions between the factors.

(i) Determine whether time limitations, cost, materials, manpower, instrumentation, machinery, other facilities, and extraneous conditions (such as weather) affect the test.

(j) Consider the possible effects of human relations on the program.

(2) Prepare a preliminary design.

(a) Outline a systematic and comprehensive schedule.

(b) Draw up a step-by-step procedure for the experiment if necessary.

(c) Eliminate the effect of variables not being studied by randomizing, controlling, and so forth.

(d) Keep the number of experimental runs to a minimum.

(e) Select the method of statistical analysis.

(f) Prepare a chart for the orderly compilation of data.

(3) Coordinate the design with all concerned parties.

(a) Adjust the program to incorporate all valid suggestions.

(b) Enumerate, in unmistakable terms, all of the steps to be followed.

d. Plan and carry out the experiment.

(1) Develop methods and procure necessary materials and equipment.

(2) Apply the predetermined methods or techniques.

(3) Doublecheck all details and modify the methods if necessary.

(4) Record any modifications of the methods or the experimental design.

(5) Check and recheck the data as they are collected.

(6) Record in detail the progress of the experiment.

e. Analyze the data.

(1) Present recorded data (if necessary) in numerical form.

(2) Apply appropriate mathematical statistical techniques.

f. Interpret the results.

(1) Consider all observed data.

(2) Draw conclusions strictly upon deductions from the evidence.

(3) Test, by independent experiments, all questions suggested by the data.

(4) Consider the technical meaning of results as well as their statistical significance.

(5) Record the implications of the findings, both for control of the process and for possible further testing.

(6) Account for any limitations imposed by the methods used.

(7) Present all results in terms of verifiable probabilities.

g. Prepare a report.

(1) Describe the experiment completely, giving the background, relevance of the problems, and meaning of the results.

(2) Use tables and graphs to present the data.

(3) Supply enough information to allow the reader to verify the results and draw his or her own conclusions.

(4) Present conclusion based on an objective summary of all evidence. Make your presentation in such a way that the results will be considered promptly and acted upon decisively.

This exhaustive checklist is presented for your guidance. You may wish to change it to suit your individual needs and you should. We want to impress upon you the necessity for using a checklist, and we merely offer this checklist as a suggestion.

Exercises (A56):

1. As an aid to designing experiments, what preparatory step should you take?

A57. Given data on a single-factor experiment, explain how to test the comparative quality of film stock and printers used in the test.

Designing a Single-Factor Experiment. To begin simply, let us help you to design an experiment for testing two batches of raw material to see if there is a significant difference between them. In your work, the raw material could be film, chemicals, or any other commodity you use in the production of precision imagery. Suppose that it is film you wish to test and that one batch was obtained from manufacturer A while the other batch was obtained from manufacturer B. You want to know if these two films will produce a product of substantially the same quality. You know that the two films are different, but you do not know what effect the differences will have on the quality of the product. For your experiment, distinguish the raw materials as "film A" and "film B." Since you are interested in the respective photographic quality of the two films, your test should consist of making controlled exposures on both films and then giving the exposed films uniform development.

If you have only one processing machine in your laboratory, you will process all film in it. But if you have two machines, you will use both in the test. If you know positively that there was no difference in the processing machines, you would ignore any machine effect on the results of your test. However, since processing machines are known to differ, you must consider possible machine effect. If you process film A in one machine and film B in the other, you are following a poorly designed experiment. You would not be able to tell whether differences existed in the films or whether differences were caused by the machines. Clearly, the machine effect would be completely "confounded" with the film effect, and you could not separate the two.

A much better experimental design would be to process samples of both films on both machines. If, as is very likely, you have a number of processing machines (N), you should assign the films to the machines at random. For example, you might assign an even number of your machines to the experiment. You would give each a number and then randomly assign film A to one-half of the total number of machines $\left(\frac{N}{2}\right)$ and film B to the other half. You can use a table of random numbers to select the machines. Doing this gives you a "completely randomized experiment." But this type of experiment has the disadvantage of throwing the machine variability together with the experimental error, and thus decreases the efficiency of the experiment. You recognize that we have designed a single-factor analysis of variance similar to the analysis with thermometers and technicians earlier in this chapter. An ANOVA chart for this experiment would contain the information shown in table 1-31. If the machine variance (σm^2) is relatively large, this design gives you an unnecessarily large residual mean square. For that reason, this design may reduce the sensitivity of the F test for detecting the differences in the film.

Exercises (A57):

1. Why would you design a single-factor experiment?

2. Suppose you had designed a single-factor experiment to test the comparative quality of film stock. Suppose, further that you used several printers in the test. Could the fact that more than one printer was used affect your outcome? Explain.

3. In the problem in exercise 2, what could you do to improve the design?

A58. Specify what you would call a design in which you selected printers at random, tried both film stocks on each machine, then took the differences in results, machine by machine, and tested the null hypothesis.

Randomized Blocks: Single Grouping to Reduce Errors. Another design that may be more efficient than the completely randomized experiment, is to make "paired" tests and take differences. In this method, you would randomly select a set of machines and test the film on them, trying both films on each machine. You would then take the difference in results, machine by machine, and determine whether the average net difference is significantly different from zero. This method, as you have undoubtedly recognized, is a two-factor analysis of variance in which the film is taken as the first factor, and the machines are taken as the second factor. The results of this experiment would be as shown in table 1–32. In this case, you have separated $(\sigma m')^2$ from $(\sigma e')^2$ in an effort to obtain a more sensitive test than you could get using the completely randomized design. You must be aware, however, that this experiment may not give you the sensitivity you expect, because now, the number of degrees of freedom upon which the residual variance is based is $\frac{N-2}{2}$ instead of N − 2. If the machine variance $(\sigma m')^2$ is small, its separation from the error

TABLE 1-31
SINGLE-FACTOR ANALYSIS OF VARIANCE

233-101

Source	SS	df	MS	Unbiased Estimate of *
Columns (Film)	- - -	1	SS Col.	$\sigma_m'^2 + \sigma_e + \left(\frac{N}{2}\right)\sigma_c'^2$
Residual (Machine plus experimental error)	- - -	N–2	SS Resid.	$\sigma_m'^2 + \sigma_e'^2$
Totals	- - -	N–1	- - -	- - -

* $\sigma_e'^2$ = error variance; $\sigma_m'^2$ = machine variance; and $\sigma_c'^2$ = column or film variance.

TABLE 1-32
2-FACTOR ANALYSIS OF VARIANCE

233-102

Source	SS	df	MS	Unbiased Estimate of *
Columns (Film)	. . .	1	SS Col.	$\sigma_e'^2 + (\frac{N}{2})\sigma_c'^2$
Rows (Machines)	. . .	$\frac{N}{2}-1$	SS Rows	$\sigma_e'^2 + 2\sigma_m'^2$
Residual (Experimental errors plus interaction)	. . .	$\frac{N}{2}-1$	SS Residual	$\sigma_e'^2$
Totals	. . .			

* $\sigma_e'^2$ = the unit error variance plus any possible interaction

variance $(\sigma e')^2$ may not be enough to offset the reduction in the degrees of freedom. In a case such as this, the completely randomized experiment may be better.

The experimental design we have just described is called a randomized block design. The name originated in agricultural research and has been carried into the language of statistical quality control. In agricultural testing, fields were divided into blocks, which in turn were divided into plots. The plots were given various treatments. In our randomized block experiment, the films are the treatments, the machines are the blocks, and the order in which the treatments are assigned constitute the plots. Thus, the experimental design is as shown in figures 1–29 and 1–30.

The ANOVA table will, in general, appear in the form shown in figure 1–31. By comparing the treatment mean square with the residual mean square, you can calculate an F score to test whether the treatments have any effect, regardless of whether there is a significant variation between blocks.

Exercises (A58):

1. What would you call a design in which you selected printers at random, tried both film stocks on each machine, then took the differences in results, machine by machine, and tested the null hypothesis?

A59. Specify the factors that must be present before you can use a Latin square design and show the differences when calculating sums of squares, degrees of freedom, and mean squares for Latin square experiments.

The Latin Square Design: Double Grouping to Reduce Errors. Very often you can reduce the error variance more by double grouping than by single grouping. For example, in testing differences in the films previously mentioned, you will have a more efficient design if you include the effect of the operators who run the machines, as you did in the three factor analysis of variance. Where you have the same number of operators and machines as the number of films you wish to test, you may use what is called the Latin square design. In the Latin square arrangement, you

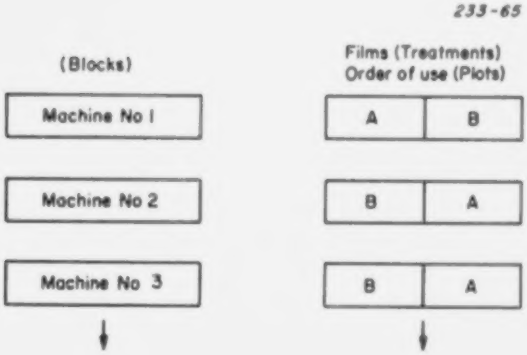

Figure 1–29. Design for "randomized block" experiments.

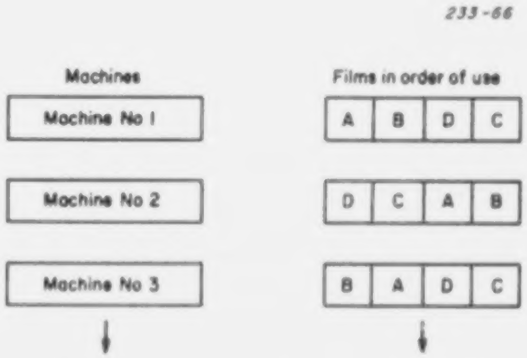

Figure 1–30. Randomized block design when several factors are involved.

233-67

Source	SS	df	MS	Unbiased Estimate of *
Treatments	....	$c-1$	S_t^2	$\sigma_e'^2 + r\sigma_t'^2$
Blocks	....	$r-1$	S_b^2	$\sigma_e'^2 + c\sigma_b'^2$
Residual	....	$(r-1)(c-1)$	S_e^2	$\sigma_e'^2$
Totals	....			

*$\sigma_e'^2$ = experimental error plus any interaction

Figure 1–31. ANOVA table for a randomized block design.

randomly assign the materials being tested to the machines and operators. Each raw material (in this case, each film) must be used only once on each machine, and only once by each operator. Figure 1–32 is an illustration of a 4 × 4 Latin square. Notice that the films, represented by A, B, C, and D, are randomly distributed among the machines and operators. Any random distribution will do as long as each film is used only once on each machine by each operator.

For example, suppose you plan to test four films that you designate as A, B, C, and D on four machines by four operators. You plan to use a standardized development to obtain an approximate gamma of 1.00. You follow the Latin square arrangement shown in figure 1–32 and accumulate the data set down in table 1–33. For convenience, the measurements are coded by subtracting 1.00 from each observed value and multiplying each by 10. Since you are maintaining the relative values, uncoding is not necessary.

Now apply the computations for an analysis of variance to these data. You have already learned the procedures for this analysis, but for the sake of emphasis, we will repeat them. The steps are:

a. Compute the correction factor by squaring the grand total and dividing by the number of individual observations.

Thus

$$\text{Correction factor} = \frac{T^2}{N} = \frac{11.0^2}{16} = \frac{121}{16} = 7.56$$

233-68

Machines	Technicians			
	I	II	III	IV
1	A	C	B	D
2	C	A	D	B
3	B	D	C	A
4	D	B	A	C

Films represented by A, B, C, and D

Figure 1–32. Latin Square design (4x4).

TABLE 1-33
GAMMA MEASUREMENTS FOR LATIN SQUARE DESIGN

233-103

Machines	Technicians								Totals
	I		II		III		IV		
1	A	1.5	C	0.5	B	1.0	D	1.5	4.5
2	C	1.0	A	0.0	D	-0.5	B	-1.0	-0.5
3	B	1.0	D	1.0	C	1.0	A	1.5	4.5
4	D	0.5	B	1.5	A	-0.5	C	1.0	2.5
Totals		4.0		3.0		1.0		3.0	11.0

A, B, C, D, = Film (measurement: gamma, coded −1X10)

Totals for films:
A = 2.5, B = 2.5, C = 3.5, D = 2.5

b. Compute the total sum of squares by squaring the individual observations, summing them, and subtracting the correction factor.

Thus

$$\begin{aligned}\text{Total SS} &= 1.5^2 + 0.5^2 + 1.0^2 + 1.5^2 + 1.0^2 + 0.0^2 \\ &\quad + -0.5^2 + -1.0^2 + 1.0^2 + 1.0^2 + 1.0^2 \\ &\quad + 1.5^2 + 0.5^2 + 1.5^2 + -0.5^2 + 1.0^2 \\ &= 17.00 - 7.56 = 9.44\end{aligned}$$

c. Compute the row sum of squares by squaring the row totals, dividing by the number of items in a row, summing the quotients, and subtracting the correction factor.

Thus

$$\text{Row SS} = \frac{4.5^2 + -0.5^2 + 4.5^2 + 2.5^2}{4} - 7.56$$

$$= \frac{47}{4} - 7.56 = 11.75 - 7.56 = 4.19$$

d. Compute the column sum of squares by summing the column totals, dividing by the number of items in a column, and subtracting the correction factor.

Thus

$$\text{Column SS} = \frac{4.0^2 + 3.0^2 + 1.0^2 + 3.0^2}{4} - 7.56$$

$$= \frac{35}{4} - 7.56 = 8.75 - 7.56 = 1.19$$

e. Compute the treatment (films) sum of squares by summing the squares of the treatment totals, dividing by the number of treatments, and subtracting the correction factor.

Thus

$$\text{Treatment SS} = \frac{2.5^2 + 2.5^2 + 3.5^2 + 2.5^2}{4} - 7.56$$

$$= \frac{31}{4} - 7.56 = 7.75 - 7.56 = 0.19$$

TABLE 1-34
ANOVA TABLE FOR LATIN SQUARE EXPERIMENT

233-104

Source	SS	df	MS
Rows (machines)	4.19	3	1.40
Columns (technicians)	1.19	3	0.40
Treatments (films)	0.19	3	0.063
Residual (experimental error plus interaction)	3.87	3	0.645
Total	9.44		

f. Compute the residual sum of squares by subtracting the sum of the values computed in steps *c*, *d*, and *e* from the value computed in step *b*.

Thus

Residual SS = 9.44 − 4.19 − 1.19 − 0.19 = 3.87

g. Enter the above sums of squares in an ANOVA table (table 1-34) and compute the mean squares.

h. The final step is to run an F test by comparing the treatment mean square with the residual mean square. You would do this in the usual way: by dividing the treatment MS by the residual MS to obtain a computed F, and then comparing the computed F with the book F, 3, 6, 0.05. In this case, the mean square for treatment is so much smaller than the mean square for residual that you can safely conclude that there is no significant difference in the films.

In this experiment; you are interested only in the films, hence you ran an F test on the treatments and not on the rows and column effects. If you care to evaluate the effect of the machines and technicians, then you should run F tests on the rows MS and the columns MS. A word of caution: If you suspect interaction, do not use Latin square designs.

Exercises (A59):

1. What is the name of the experimental design in which you try to reduce errors by double grouping?

2. What factors must be present before you can use a Latin square design?

Machines	Technicians				
	I	II	III	IV	
1	Ac	Ba	Cb	Dd	Films are represented
2	Bd	Ab	Da	Cc	by A, B, C, and D
3	Ca	Dc	Ad	Bb	Days are represented
4	Db	Cd	Bc	Aa	by a, b, c, and d

Figure 1-33. Arrangement of data for a Graeco-Latin square design.

3. Are there any differences in calculating sums of squares, degrees of freedom, and mean squares for Latin square experiments?

A60. Specify what design involves triple grouping to reduce errors.

Graeco-Latin Squares: Triple Grouping to Reduce Errors. Triple grouping may increase the efficiency of an experiment even more than either double or single grouping. For instance, your test for significant differences in films might be made more sensitive if you also considered the days upon which the tests were run. Here again, you must arrange to have the treatments and the days assigned at random, making certain that each film will be used once on each day, once by each technician, and once on each machine. This design is called a Graeco-Latin square, and its arrangement is as shown in figure 1-33.

You run an analysis of variance of a Graeco-Latin square following the same procedure you used for the Latin square except that now you must also find the sum of squares and the mean square for days in addition to the other factors. The sum of squares for days is computed by summing the squares of the a, b, c, and d totals, dividing by the number of days, and subtracting the correction factor. As usual, you find the mean square by dividing the sum of squares for days by the degrees of freedom for days. The residual sum of squares for the Graeco-Latin square is (N − 1) (N − 3).

This completes our discussion of experimental design. You see that we have confined it to the same area that we covered in analysis of variance for the reasons that were stated at the beginning of this section. We do wish to impress upon you that this knowledge of experimental design is just the beginning. Should your requirements warrant advanced statistical quality control analysis, then you will have to pursue the subject of design of experiments to greater lengths. However, we feel that, armed with the knowledge obtained from this chapter, you should be able to function effectively and should be well prepared to expand your knowledge in the AFSC.

Exercises (A60):

1. What design involves triple grouping to reduce errors?

Statistical Evaluation of Chemical Procedures

AS A SUPERVISOR, a potential supervisor, or skilled technician, you are vitally concerned with the evaluation of many chemical procedures. In order to make an evaluation, it is necessary for you to collect data, statistically analyze it, and eventually construct the necessary control charts. You have learned how to make sensitometric tests, chemical analyses, and many other operational checks in order to produce raw data. Eventually, you must assemble such raw data into a meaningful form.

Statistical control is very important to your kind of mass production, high-quality imagery. Through statistical control methods, you reduce raw data to meaningful products or process data. By arranging, plotting, and analyzing the data, you produce norms and limits for the process. Once these norms and limits are placed into the system, the system operates successfully. However, this is not the end. You must continue data analysis to determine how well the process is continuing and to determine when changes are needed. The data you are concerned with is almost any continuing or discrete photographic data such as specific gravity, pH tests, D-log-E graphs, density, and total alkalinity tests.

From your previous study of statistics, you may recall the term "variability." This term signifies change, uncertainty, and deviation. The term "variance" is a mathematical expression used to describe the measurement of variability. Variability is characteristic of all things in nature as well as manmade products or processes (the photo process is no exception). No two natural objects, manmade products, or processes are exactly alike. Some differences, however slight, always exist.

Since you work in a field that is highly technical, you are forced to recognize the existence and importance of variability. You will need to measure it, to record it, and to control it within certain limits. Most of the time you do this by sampling, by graphing and charting the data samples, by assigning numerical values to the deviations, and by controlling future operations through application of the knowledge gained. In some instances, you may consider all the products or process measurements—if the number is not too great—such as would be the case with specific gravity or similar tests where the number of cases is not excessive. Other measurements must be obtained by sampling representative parts of the entire amount.

As we mentioned, you reduce raw data to a form that clearly shows how much variability exists. There are a number of methods useful as display devices. Before you can display information, however, you must first record it. Thus, let us start by examining this phase of the operation.

2–1. Laboratory Data Collection

To insure that your chemical control laboratory functions at top efficiency, you must maintain records of the operation. Such information is gained by examination of all records maintained in the lab. Laboratory notebooks are a prime source of information. This information is supplemented by such things as machines (printer, processor, densitometer, sensitometer, etc.), operational records, technical calculations, chemical mix records, D-log-E plots, replenishment data, and chemical sampling data—in fact, any bits of information are useful. Let's take a specific example of data and arrange it in a form that permits us to extract some recognizable information.

A61. Define variability, tolerance, mean, median, and mode. Given data on frequency distribution, describe the activity of the curve. Given data on the limits of a process, describe the activity of the process. Given data on the variability and acceptable limits of a distribution curve, specify the process.

Frequency Distribution. One of the basic tools for analyzing variability is the construction of a frequency distribution. We are reasonably certain that variability exists in all things, but we also believe that tolerance exists. When the variability between things is within certain limits of tolerance, there is no significant difference between them.

You will recall from your previous study of statistics that two types of data are available. These are discrete and continuous. Discrete data varies in jumps, and it can be counted (for example, density readings, gamma readings, and pH). Continuous data is data that progresses continuously and must be gathered into groups or cells before analysis.

Let us consider a discrete data collection of values and arrange the values into a frequency distribution so that we can gain some information. Assume that you have been processing film in a machine. Using a random method, you have spliced in 33 "sensi" strips. After processing, these strips are read on a densitometer, the results are plotted, and D-log-E curves are constructed. Gamma values are computed from the curves. These values are a follows:

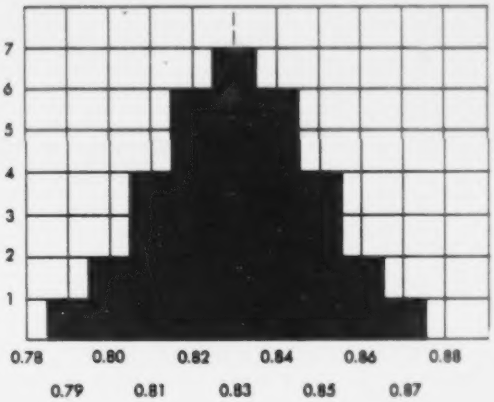

Figure 2-1. Frequency histogram.

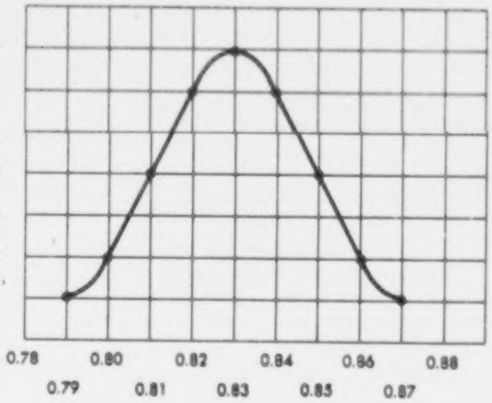

Figure 2-2. Gaussian curve.

0.83	0.87	0.81	0.85
0.86	0.83	0.83	0.85
0.80	0.84	0.85	0.84
0.83	0.79	0.85	0.81
0.82	0.83	0.84	0.82
0.83	0.84	0.81	0.82
0.82	0.86	0.84	0.82
0.82	0.80	0.81	0.83
			0.84

An examination of the above list yields little information. If we arrange these values in a graphical form (frequency histogram) as shown in figure 2-1, we can see the number of times each gamma occurred. For example, 0.83 gamma was obtained from seven "sensi" strips. A more conventional plot might look like figure 2-2. You will recognize this as a Gaussian curve. The shape is characteristic of a normal operation. If experience has shown that a gamma range of 0.79 to 0.87 is an acceptable variance, you have no worry about this part of the operation. Your processor is moving film at the correct speed, the solutions are at correct temperature, replenishment is accurate, chemical formulary is good, etc.

If, during the process of development, some unusual factor enters in and results in a gradual upward shift in gamma, the curve resulting from plotting these points might appear as in figure 2-3. A distribution such as this is known as a skewed distribution; and according to the process it was subjected to, it may be skewed either to the right or to the left of the centerline. You will note tha[illegible]eration is still in tolerance according to our previous variance (0.08) of 0.79 to 0.87. However, it would be desirable to investigate the reason for the variance. It is possible that this is a signal for a potential out-of-tolerance situation. The variation shows that the process mode is rising and has reached 0.85. If the mode eventually equals the upper control limit, it is reasonable to suppose that some readings will exceed the variability limit. In our example, we started with 33 cases plotted to a Gaussian curve. The next 33 cases plotted to a distribution as shown in figure 2-3. Now, where do you look to determine the reason for the skewed curve? In general, the number of cases with higher-than-normal gamma has increased. If the second set of 33 cases was started with a new batch of developer, but no other variable could be found, it could be supposed that the new batch was improperly compounded—possibly too much accelerator. In any event, the new mix should be quantitatively analyzed. In actual practice, the improper mix would normally have been identified long before this.

Should the degree of control be especially accurate, or should there be a very small deviation from the average, the result then will be a distribution that has been affected by kurtosis. Kurtosis may (in this case) be defined as the degree of peakedness of the distribution curve. This peakedness results when the vertical plot is raised and the dimension of the horizontal plot is compressed. A frequency histogram that shows kurtosis is illustrated in figure 2-4.

By studying frequency distribution curves, you can derive a certain amount of information. For example, we have already said that kurtosis could result when the degree of control is especially accurate. Any curve that is subjected to kurtosis should be compared to what is considered a normal distribution curve. If our curve (or histogram) shows kurtosis as indicated in figure 2-4 (especially

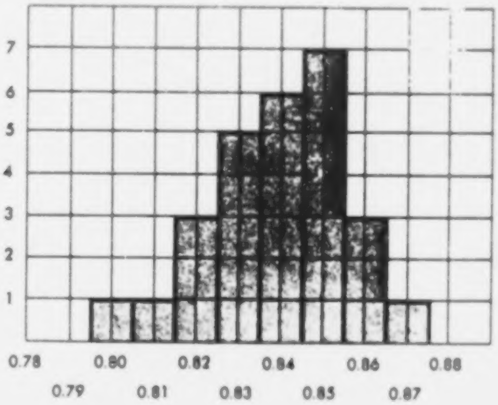

Figure 2-3. Skewed distribution.

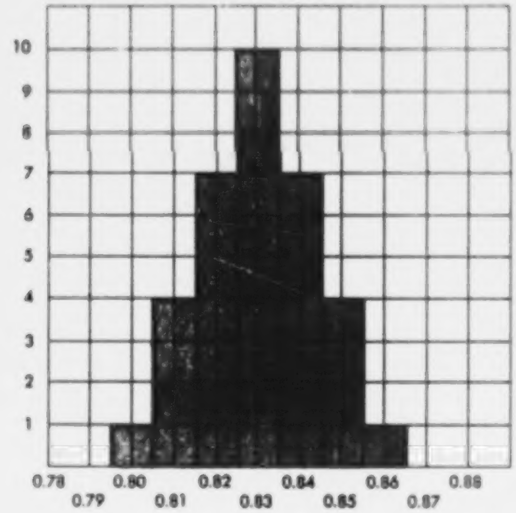

Figure 2-4. Kurtosis.

accurate control), it may be that such process accuracy is not necessary. We said that the limits were densities of 0.79 and 0.87. If such a product is acceptable, we are spending too much money for unneeded accuracy. Realize that accurate control takes considerable manpower and man-hours to accomplish.

Further analysis of the distribution we have studied can (if desired) be the determination of the mean, the median, and the mode, which we discussed in Chapter 1. The mean, medians, and mode values are often analyzed and plotted separately to provide a greater insight of an operation. For example, the plotting of just a mean (average value) will not show a bimodal distribution.

Exercises (A61):

1. A density of 1.0 is read on a densitometer by 10 people. The readings range from 0.9 to 1.1. However, all these readings are acceptable to the process. Define the variability and tolerance.

2. A normal frequency distribution has existed for 50 cases. The next 25 cases are much higher in value. If all cases are plotted together, what is the shift of the curve called?

3. The limits of a process are 0.5 to 1.5. Fifty cases are plotted to a Gaussian curve. The next 100 cases show a variability range of 0.95 to 1.05. What would the curve of the 150 cases look like? What can we say that the curve exhibits?

4. If a distribution curve shows a variability of 0.9 to 1.1, and the acceptable limits are 0.3 to 1.3, what can we say about the process?

A62. Given a statement on the collecting and analyzing of specific gravity readings to be used to analyze machine thermostat malfunctions, determine the validity of this test.

Validity. Unless a particular test is measuring what it is intended to measure, it is not serving its purpose. In fact, it is very possible that the test (for example, specific gravity) is measuring factors that are not related to the real objectives of the test itself. If the results of any test are treated as though the test is measuring what is intended, when in fact it is not, the test may be misleading and harmful. You should determine the validity of each test so that you can increase its validity in the future.

Procedures for measuring the validity of a test range from merely inspecting the results in the light of the objectives to such things as computing validity coefficients by complex statistical procedures. The method you use for determining the validity should take into consideration your skill, time limitations, facilities, and the research data available to you. The validity of your chemical tests can be determined only by comparing the results of the test with the standards that have been set up in your laboratory. With respect to sensitometric tests, it is almost impossible to set up a completely satisfactory criterion of validity in all cases. You should never assume that any particular sensitometric test or related procedure is valid merely because you prepared it. Constantly look for ways in which validity can be improved.

Exercises (A62):

1. You have collected and analyzed specific gravity readings over a period of time and are using this analysis to help determine the extent of machine thermostat malfunctions. Is this a valid test?

A63. Define "reliability" in terms of photographic tests.

Reliability. To determine the reliability of chemical quality control tests, it is necessary to find out just how consistently the tests are making their measurements. No outside criterion need be considered, because reliability is not concerned with the nature of things measured by the test. What is important is that the same measurements, whatever they are, be obtained over and over again under identical circumstances.

While there are many formulas used for obtaining an index of reliability, these elaborate formulas do not need to be applied in all instances. Generally speaking, when you are utilizing standardized chemical quality control checks, it is readily apparent when the reliability of the check appears to be drifting away from the normal established as a result of previous quality control checks.

It stands to reason that all chemical quality control checks should be reliable, and it is relatively simple to estimate the degree of reliability. A quality control check is reliable if, when the same test or its equivalent is given a second time to the same sample or samples, the results are essentially the same.

When we know that a particular procedure is reliable, we know that we can repeat this procedure any number of times and still have a pretty good idea of what the results would be if that particular procedure, or another one like it, is to be repeated a number of times by the same personnel. The amount of agreement found between these various runs can be expressed as the correlation between the runs. If each quality control procedure is dependable, in the sense of being consistent in the way it produces results from individuals in relation to the group, and if the procedures used by two individuals have the same kind of content, then the procedures should agree with each other quite well. When two procedures or two runs of the same procedure so agree, we say that the correlation between them is high. It should be noted that a high degree of agreement between various runs of the same test or different tests is associated with two conditions: the quality control procedures must yield a dependable result and the procedures must be designed to measure the same thing.

Exercises (A63):

1. Define "reliability" in terms of photographic tests.

A64. Given data on a photographic process based on gamma values, determine how many processed "sensi" strips are rejected. Given data on "sensi" strips processed under like conditions, determine the tolerance in standard deviation. Given a statement on a frequency distribution curve of gamma readings established for a certain process, explain the specific processing error when the curve starts to flatten out.

Standard Deviation. In Chapter 1 of this volume you studied standard deviation (SD) and learned its significance. Now, let us apply such a computation to the values of gamma we used in our previous frequency distribution. Using the same 33 values, you will find that standard deviation is computed as follows:

$$SD = \sqrt{\frac{22.744}{33} - (0.83)^2}$$

$$= \sqrt{\frac{22.744}{33} - 0.6889}$$

$$= \sqrt{0.6892 - 0.6889}$$

$$= \sqrt{0.0003}$$

$$= 0.0176$$

Let us assume a hypothetical case where we are starting operation in a laboratory with a new developer. We know nothing about the product until we have produced a number of negatives. At the beginning, much of the processing technique is educated guesswork based on sound principles and experience. We start by processing film and accumulating raw data. Part of the raw data is obtained by processing sensitometric strips along with the film. Thus, assuming that the processing is standarized as to temperature, type of film, etc., we compute a gamma value for each sensitometric strip processed over a specified period of time. As an arbitrary figure, let us say we process 33 sensitometric strips during our test run; this is part of our sampling of the process. We then plot the curves and find 33 values of gamma and compute an SD of 0.0173. Thus, the standard deviation of this distribution is a gamma value of 0.0173.

Standard deviation is nothing more than a method of expressing the variation of data from an average or a mean. The formula for the calculation of standard deviation is so constructed that when you lay out this figure of 0.0173 from each side of the mean gamma value of 0.83, 68 percent of the gamma readings will fall within the plotted limits. Refer to figure 2-5 for the graphical representation of this frequency distribution. Note that the mean gamma is 0.83. A gamma of 0.83 plus a deviation of 0.0173 establishes the upper limit of 0.8127. Thus, the range from 0.8473 to 0.8127 is one standard deviation in terms of gamma. A standard deviation of two or a standard deviation of three is plotted in the same manner, still working from both sides of the mean. At two standard deviations, more than 98 percent of the data is included; and at three standard deviations, approximately 95 percent of the data is included. It should, at this time, be apparent that figure 2-5 depicts the standard deviation of a more or less normal curve that includes no definite irregularities.

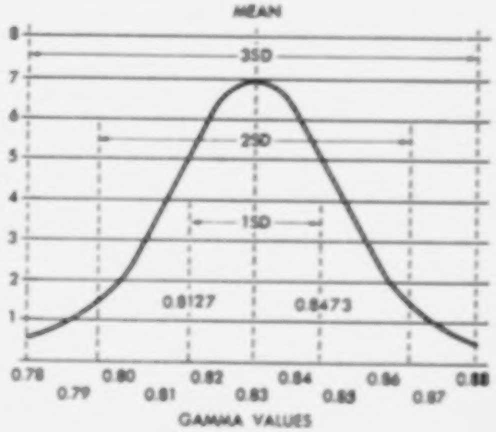

Figure 2-5. Standard deviation for a normal curve.

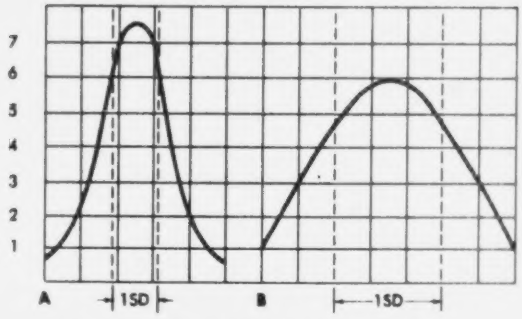

Figure 2–6. Standard deviation for modified curves.

A normal curve, such as above, is often an ideal situation, but certain factors may cause a change. If our curve were affected by kurtosis, it might assume a shape as shown in figure 2-6, part A. In this case, one standard deviation would still encompass 68 percent of the data, but the limits would be much narrower than apparent in the so-called normal curve. If, on the other extreme, the curve were low and flat as shown in part B of this figure and the data were spread out to a greater extent, the standard deviation would have a much wider range in order to encompass 68 percent of the data.

Let us think for a moment of what standard deviation means in terms of its application to the sensitometric strips whose gamma we have tabulated. Going back to figure 2-5, we might determine that one standard deviation was the limit of a usable product. Gammas from approximately 0.81 to 0.85 include a good product, but gammas below and above these limits result in rejects. This means we must alter our process in order to eliminate the rejects. Analyzing the process and applying similar statistical analyses to other parameters of the total process might tell us that the machine thermostats were maladjusted, which then produced temperature fluctuations—the result being both over and under development. We now make the necessary repairs or adjustments to the thermostats and continue processing additional film along with a new set of sensitometric strips. Now, another 33 strips are plotted for gammas, and a new frequency tabulation of these gamma values is made. We now hope that the variance will be 0.81 to 0.85. Remember, no other change was made in the process except the thermostat adjustments. If our new frequency tabulation does not show any significant change, the cause must be elsewhere. If the thermostat adjustments solved our problem, the new distribution would exhibit kurtosis if it were plotted on top of the original curve.

If the original curve shown in figure 2-5 were the result of a completely acceptable product with no rejects, we have no problem and the process is good up to three standard deviations. However, it is still necessary to continue running sensitometric strips in with the product at random intervals. At the moment all portions of the process are within tolerance, but the thermostats or any other factor affecting the process could vary at some future time. The curve could start flattening out, or a skew might develop. This is an immediate signal that something is causing the process to exceed certain limits. This would signal us to look for the cause.

In general, a frequency tabulation and the construction of its curve, such as we have discussed, are accomplished at the beginning of a process as an aid in standardization. Once the standard has been established (whether it be gamma, specific gravity, temperature, pH, etc.), the standardized limits of the process are plotted on various types of control charts to simplify future operations.

In our statistical analysis, we have considered a number of gamma readings and determined the standard deviation limit that we can tolerate. Similar methods of computation are used to obtain a tolerance for any factor we decide to study. For example, we can, over a period of time, calculate the effect of change in total alkalinity readings and establish a maximum standard deviation for this factor.

You should note that a frequency distribution does not, in itself, pinpoint the cause of a problem. Rather, it says that a problem exists. If gamma readings are out of tolerance, the cause may be any one of a number of things. For example, high gamma could be attributed to improper developer compounding, improper replenishment, high temperature, low machine transport speed, etc. It is now your problem to determine the actual cause of the high gamma and correct it.

It is desirable that information we have obtained relative to variance be collected and displayed on some type of control chart. Such a chart should show an optimum value and allow tolerances called upper control limit (UCL) and a lower control limit (LCL). Let's see how such a chart is constructed.

Exercises (A64):

1. Define standard deviation.

2. Your photographic process requires the rejection of anything over a standard deviation of one in gamma values. The distribution produces a Gaussian curve based on 100 gamma values. How many of the processed "sensi" strips are rejects?

3. Fifty "sensi" strips processed under like conditions produce a distribution of gamma values from 0.7 to 1.1. All the strips are within tolerance and the plot is a Gaussian curve. What is the tolerance in standard deviation?

4. You have a frequency distribution curve of gamma readings established for a certain process. This curve starts to flatten out. What is the specific processing error?

2–2. Control Charts

Nothing in life is absolutely constant. Extensive observation shows the existence of what can be called the *constant-cause system*. By this we mean that a repetitive process produces results that vary, but the variance falls within certain limits *most of the time*. We can thus say that we have a reasonable stable fluctuation that is in statistical control. Such a fluctuation around a mean is plotted on a control chart. The chart is our means of knowing whether or not our process is being maintained within the established limits. Such charts are used in chemistry, sensitometry, and final product quality control.

There are two basic types of control charts. If the centerline delineates the process average (the symbol X signifies individual observations and the bar over the X indicates that the individual values are averaged), the chart is called a chart of averages or an $\overline{X}$ ($\overline{X}$-bar). The second basic control chart type is called an $\overline{R}$ (R-bar) chart or range chart and is based on the ranges of values of the observed individual observations.

A65. Given a statement on processing and plotting "sensi" strips under identical conditions, determine what happens when the gamma varies from one strip to another; identify what establishes the UCL and the LCL of a $\overline{X}$ chart; given data on plotting pH values on a control chart, identify your cause for concern if a series of plots are slowly moving toward the control limit and when they start back toward the mean.

The $\overline{X}$ Chart. We have seen how a series of happenings can be arranged into a frequency histogram from which we can derive a curve. Also, we have seen that there is a standard deviation from the process average that lets us know what percentage of occurences fall where. Now, let us see how this information can be monitored with a control chart. The $\overline{X}$ chart is is a chart for averages and is also referred to as a Shewhart chart. It is a long chart whose horizontal axis may be marked off in units of time, frequency, or some subgroup number, and whose vertical axis is marked off in whatever unit of value is given to your observed samples. As an example, let's assume that your chart records pH values taken at some particular interval (or varying intervals.)

Your process is begun, your samples are being taken, and your observations are being plotted. After a period of time, your control chart begins to look like figure 2-7, part A. Now you can average your observations and draw a line to indicate the process mean ($\overline{X}$) as shown in figure 2–7, part B. You can see that if all of the observations you have been recording were plotted in accordance with their frequency of occurrence and the occurrences have a normal distribution, they would indicate a distribution that would fall under a Gaussian curve as shown in part C of figure 2-7.

Moreover, you can now figure standard deviation for this curve and extend the values down the length of your chart to give you your limits. These limits are shown as UCL and LCL in part D of figure 2-7, and the chart shows a three-standard deviation limit. A limit such as this may be equivalent to one pH and may be an excessive variation. Thus, you will need to tighten up the process and use the limits of a standard deviation of 2 for an acceptable product.

These are your process control limits that tell you at a glance just how your process is behaving. You may use these limits, or if you wish to work to closer tolerances, you may add your own *acceptance* limits. The control limits you decide upon are labeled on your graph as UCL for *upper control limit* and LCL for *lower control limit*.

Occasionally, a point may fall outside of your control limits. This does not mean that your process has gone bad. The out-of-control observation may be due to *chance* causes, and, if so, your process will return to within the limits shortly. Even several points falling progressively toward a control limit would not necessarily indicate that corrective action must be taken. It often requires five to seven points to establish a trend.

Sometimes out-of-control points are due to *assignable causes*. That is, there is some reason other than chance responsible for the behavior of your process. If the assignable cause remains, the process will be affected, and the cause must be removed. Once in a while an assignable cause will occur only once and never be repeated. In that case, it can be considered and treated as a chance cause.

Exercises (A65):

1. You are processing and plotting "sensi" strips under identical conditions and find that the gamma varies from one strip to another. Is this cause for worry?

2. What is indicated on the vertical axis of the Shewhart chart?

3. UCL and LCL on an $\overline{X}$ chart are usually established from what kind of computation?

4. You are plotting pH values on a control chart. A series of plots is slowly moving toward the control limit but level out almost at the limit and stay there. Is there cause for concern? What if they start back toward the mean and stay there?

5. If a process is under control but one plot falls beyond the limit, what action do you take? What will you do if six consecutive plots fall toward the LCL?

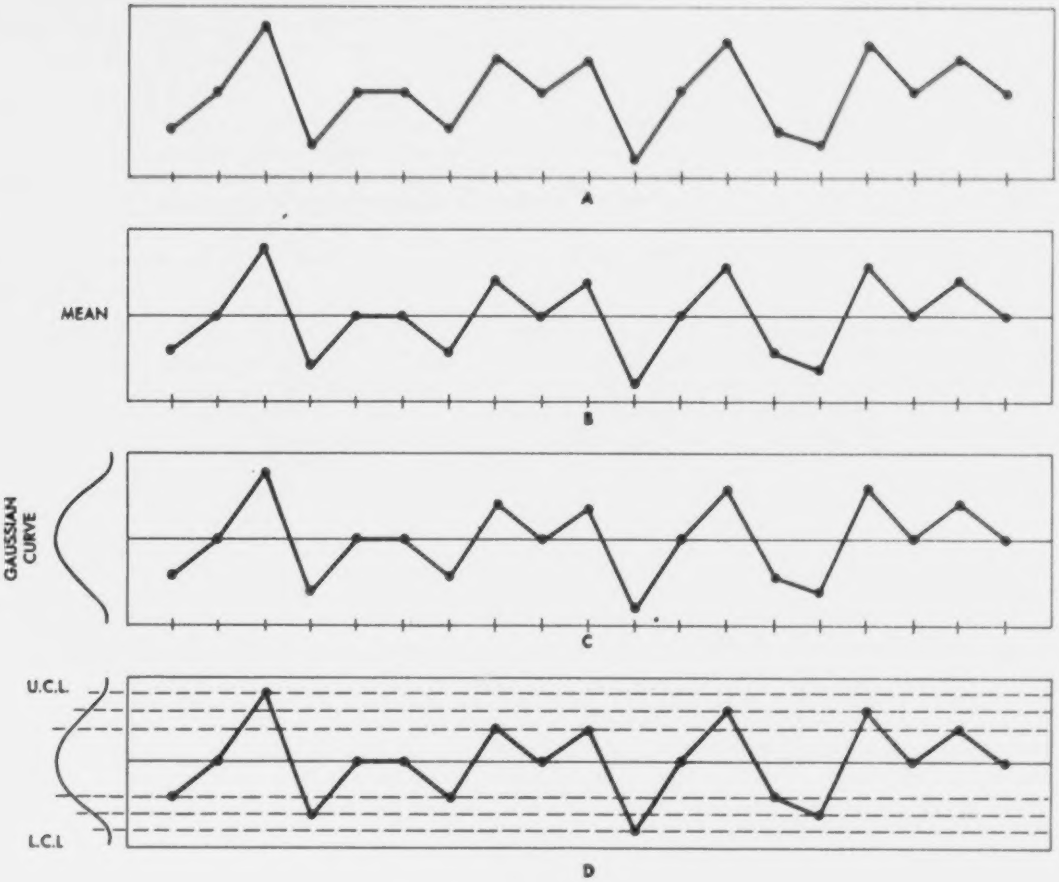

Figure 2–7. Control chart development.

A66. Given a statement on plotting "sensi" steps to check density over a period of time, and the plotting of only step 6 (mid-density) of each strip, determine if this information is of value.

Density Control Chart. A control chart, such as the one in figure 2-8 that shows the density plots of three different steps of a sensitometric strip, means nothing but extra work unless you put it to use. Don't make charts just for the sake of making charts! (NOTE: This is a variation of our previous X chart, and we are going to plot densities obtained from "sensi" strips.)

The first thing a density control chart should do is to show whether or not your film processing conditions are being properly maintained. This type of chart will also help you detect trends and variations in your processing setup which could seriously affect product quality if left unattended. Each plot gives a numerical measurement of the process; a series of plots will indicate whether or not you should take any corrective action.

It is important to remember that the tolerance limits on each value have a purpose, too. Small, random variations in a series of plots are normal; you should be concerned with the trends and out-of-control plots. The letters, such as A, B, and C in figure 2–8, indicate the sequence of control strips for a particular day. The numbers, such as 1, 2, and 3, indicate the day of the month. Thus, the plot identified by 1A is the first control strip plotted on the first day of the month, while 3C is the third strip plotted on the third day of the month. The plots for strips 3C and 3D of step 3 have exceeded the tolerance limit. The plot for strip 9B of step 3 has just reached the upper limit line. Any plot that reaches or exceeds a tolerance line should be circled.

A circled plot means it is time for you to make a decision. When it appears that several processing errors, all in the same direction, have accumulated to cause the plot to establish a pattern, it is best to process "check" control strips such as at 3C and 3D. As you can see, when strip 3D was plotted, it stayed outside the tolerance limit. The chemicals were dumped (assuming this was the problem), and a fresh start was made on the fourth day. With new chemicals, the process was well within tolerance. The plots for strips 8B through 9B of step 3 show the result of what is called a short-term variability. The plots of the control strip gradually moved toward the upper tolerance limit but soon returned to a satisfactory level.

In addition to step 3 of the 11-step sensitometric strip, the densities of steps 6 and 9 are also plotted. Thus, we plot high, medium, and low densities. By comparing the three density plots of an identical sensitometric strip, additional comparative information is obtained. In addition, a fourth plot could be made indicating the density difference between, say, step 3 and step 9. Variations in what information is to be plotted are endless. These variations should be planned so that only desirable and useful information is charted.

Exercises (A66):

1. You are plotting "sensi" steps to check density over a period of time. You plot only step 6 (mid density) of each strip. Is this information of value?

A67. Specify what information is needed to construct a range chart and list typical charts that could be used as a part of statistical analysis in a imagery production laboratory.

Range Chart. A range chart (R) is similar to an X chart except for the information it contains. For example, you might wish to keep a record of how a developer is maintaining its pH. You might read five samples at various times over a period of several days and your accumulated data might be:

	Samples						
Day	1	2	3	4	5	Range	X
1	10.9	10.4	9.7	10.6	10.2	1.2	10.36
2	10.3	9.5	9.2	9.8	10.7	1.5	9.90
3	11.4	10.5	10.7	9.6	10.2	1.8	10.48
4	10.7	10.1	10.5	10.5	10.2	.6	10.40
5	10.2	10.3	9.5	9.8	10.1	.8	9.98
6	9.7	9.9	10.0	10.4	10.3	.7	10.06
						6 6.6	61.18
						1.1 = R	10.20=

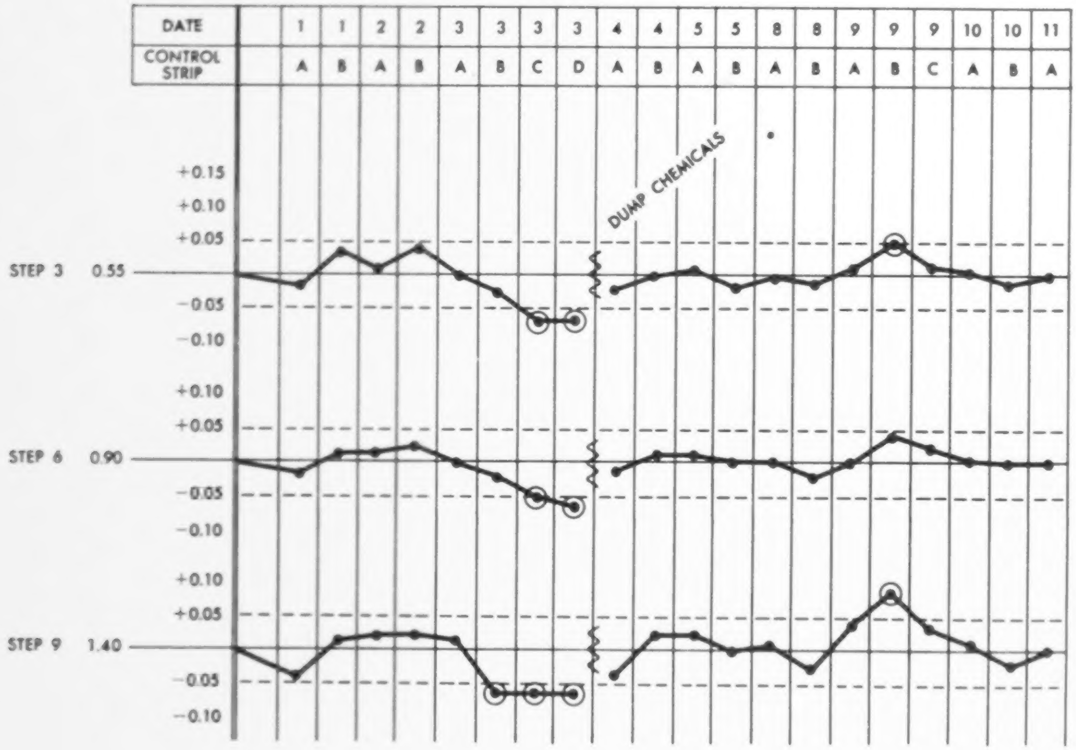

Figure 2-8. Density control chart.

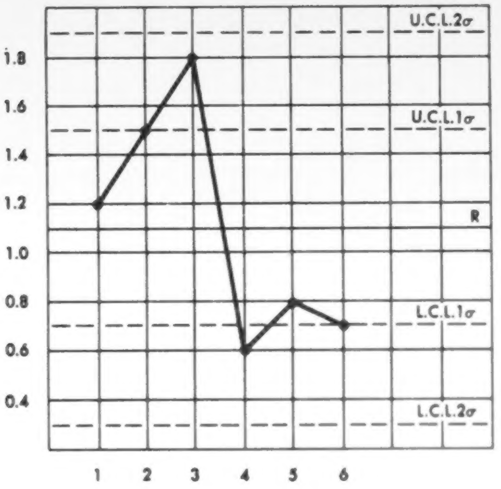

Figure 2–9. Range chart.

You have the averages of the individual readings and also their range. The range, as previously stated, is the minimum value subtracted from the maximum value. This information is then plotted on a control chart, as seen in figure 2-9. The ranges computed during days 1 through 6 will form a frequency distribution, and a standard deviation can be plotted and used to establish control limits. However, there are other factors to be considered in figuring control limits. A minimum range would be zero; therefore, it is possible to set the lower control limit on a range chart to zero.

After a period of time, your process average and your standard deviation will indicate how well you are operating. If more stringent requirements are placed upon your control, acceptance limits can be placed on your control charts, and your operation can be made to stay within these limits. If you are successful in this, your frequency distribution will change, and you should recalculate it and the standard deviation. This procedure will be substantially the same for any area of control, whether it be gamma, pH, or other.

In addition to the charts we have mentioned, there are many other statistical charts applicable to the evaluation of chemical procedures. Some of these charts are as follows:

- Standard deviation charts.
- Fraction defective charts.
- Percent defective charts.
- Number defective charts.
- Defects per unit charts.
- Demerit charts.

If you desire to know more about these charts, we suggest any one of the many commercial books written on this subject. In general, the charts we have covered are the ones used most often for the evaluation of chemical procedures. Additionally, you will find that many laboratories have developed special charts to serve a particular local purpose.

Exercises (A67):

1. Values used to construct a typical range chart will include what information?

2. In addition to charts for averages and range charts, what are some other typical charts that could be used as a part of statistical analysis in a imagery production laboratory?

2–3. Applied Statistical Control and Evaluation

In this section, we are going to apply certain statistical controls to the evaluation of a developing solution and establish a replenishment program. Essentially, this is an actual procedure used in a training course. Many of the concepts may be applied to other types of analyses. A small amount of developing solution is used, film is processed until the solution is exhausted, and then the developer is analyzed to determine the content of the replenisher.

A68. State what information is obtained when establishing a replenishment program that requires that the D-log-E curves be processed and read at various stages of developer usage; specify how an excess of KBr can be reduced when compounding a replenisher.

Analysis Overview. The first film to be developed consisted of 10 step-wedges processed in a small amount of developer. The strips were read on a densitometer and a standard deviation (sigma) of three was established. In all the following batches of film (sheets are used in the interests of economy), 18 sheets of film were developed at one time—two of these 18 sheets are sensitometric wedges. The findings from the two wedges were averaged. This procedure was repeated until the developer was exhausted. As processing continued, the "sensi" strips were read and a graph was constructed. The graph contained readings for D/max, D/min, toe, shoulder, gamma, and fog level.

The replenishment requirements are determined by analyzing the solution after exhaustion. Table 2-1 shows a typical example of desired information. Note that the KBr increased from the original 1 gram/l to 2 grams/l. In order to reduce the KBr to proper concentration, 1.5 liters of water were to be added to each liter of exhausted developer. This would return the KBr to 1 gram/l. To this water, the other chemical deficiencies were added, plus an amount in proportion to the original content. Naturally, no KBr was included. This solution was then a replenisher of the proper strength. The grams/l of any chemical except KBr in the replenisher would be the difference found in a specific chemical between the original solution and the exhausted solution, plus an amount in proportion to the original solution.

TABLE 2-1
SOLUTION ANALYSIS

CHEMICAL	ORIGINAL g/l IN SOLUTION	EXISTING g/l AFTER 250 SHEETS	DIFFERENCE IN ORIGINAL AND USED SOLUTION	ORIGINAL g/l	REPLENISHER g/l
Metol	2.0	1.5	0.5	2.0	2.5
Na_2SO_3	40.0	32.0	8.0	40	48
Hq	5.0	4.1	0.9	5.0	5.9
Na_2CO_3	60.0	48.0	12.0	60.0	72.0
KBr	1.0	2.5	Increase	1.0	0.0

The rate of replenishment can be found as follows: Assume 3000 ml (3 liters) of exhausted solution. For each liter, 1.5 liters of water are needed to reduce the KBr content. In this case, 4.5 liters of replenisher are needed for 3 liters of developer. The total volume of replenisher is 4500 ml. Divide this by 250 (the film unit), which can be sheets, rolls, or feet. The answer is 18. Thus, the rate of replenishment is 18 ml of replenisher added per unit of film processed.

Exercises (A68):

1. Establishing a replenishment program requires that D-log-E curves be processed and read at various stages of developer usage. What is the resulting information obtained from this procedure?

2. After quantitative analysis of a developer, you find that there is an excess of KBr. How is this excess reduced when compounding a replenisher?

A69. State why in establishing a replenisher formula, the first step is to quantitatively analyze the fresh developer and indicate how you establish the proper development time to be used as a standard when you determine a replenisher.

Analysis Procedure. Let's consider an actual example. Refer to figure 2-10 through 2-18 as you progress. Prior to, during, and after developer exhaustion, the solution was analyzed for metol, hydroquinone, SO_3, CO_3, pH, TA, BI, and KBr. The formula used was as follows and a total of 16 liters was prepared.

Metol—1.5 grams/l
Na_2SO_3 desiccated—45 grams/l
Hydroquinone—3.0 grams/l
Na_2CO_3 monohydrated—6.0 grams/l
KBr—0.8 grams/l

Chemical quantitative analysis of the fresh developer was accomplished before any film was processed. The results were as follows (see table 2-2):

- Metol-original 1.5 grams/l; found 1.55 grams/l by method BW−407B.
- Hydroquinone-original 3.0 grams/l; found 3.06 grams/l by method BW−407B.
- Na_2SO_3-original 45.0 grams/l; found 44 grams/l.
- Na_2CO_3-original 6.0 grams/l: found 7.34 grams/l.
- KBr-original 0.8 grams/l; found 0.76 grams/l by method BW-930B.

NOTE: Combined determination by H_2SO_4. Iodine findings for sulfite and not more than 5 drops of 0.1 percent phenolpthalein indicator for carbonate.

In addition to the above analysis, the fresh solution was also analyzed for the following (see table 2−2):

- pH (9.79)—Using a 100-ml sample at 80°FF. (± 1/2°F), a reading of 9.79 was obtained. The pH meter was previously checked with two buffers bracketing the expected pH.
- BI (3.61)—The same 100-ml sample was titrated with 1N HCl using 1-ml increments or less until the pH of the solution had dropped exactly 1 pH. To calculate: BI = 1N HCl X M1 HCl.
- TA (1.85)—Using the above 100-ml sample, continue titrating with HCl to bring the pH down to 4. This is also the indicating point of bromocresol green. To calculate: TA = 1N HCl X M1 HCl X 0.04.

To determine proper development time for the fresh developer, three 11-step "sensi" strips were printed on an EK Model 101 sensitometer. The rheostat was set at 0.836 amperes and a neutral density of 1.93 was used. The three strips were developed in a 4-liter quantity of developer for 5, 7, and 9 minutes, respectively. The D-log-E curve of the 5-minute strip showed proper development and had a D/max of 1.80, mid-density of 0.96, and D/min of 0.12, a base fog of 0.10, a gamma of 0.75, and an ASA speed of 47.4. Temperature of the developer was 68.5°F.

Continuing with this project, a 4-liter quantity of the fresh developer was exhausted by processing 300 sheets of 4- by 5-inch film (fig. 2-10). The developer was then

TABLE 2-2
CHEMICAL ANALYSIS DETERMINATIONS

CHEMICAL	ORIGINAL g/l BY WGT. (a)	ORIGINAL ANALYSIS g/l (b)	EXHAUSTED g/l 300 SHT (c)	BY EXHAUS. + - g/l (d)	g/l IN REPLEN. ORIG + COL. (d) (e)
Metol	1.5	1.55	1.28	-.27	1.82
SO3	45.0 dess.	44.0 des.	43.60 des.	-.40	44.40
HQ	3.0	3.06	2.96	-.10	3.16
CO3	6.0 mono.	7.34 mono.	4.68	-2.66	10.00
KBr	.8	.76	2.17	+1.41	0.0
pH		9.79	9.43		
TA		1.85 (100 ml)	1.78 (100 ml)		
BI		3.61 (100 ml)	3.08 (100 ml)		

NOTE: THE DEVELOPER WAS ASSUMED TO BE EXHAUSTED AFTER 300 SHEETS OF 4 X 5 FILM HAD BEEN PROCESSED. THE FRESH SOLUTION TOTALED 4,000 ml AND AFTER IT WAS EXHAUSTED THERE WERE 3,196 ml REMAINING.

analyzed for content. Note that the exhausted developer contained 2.17 grams/l of KBr. The replenishment calculation starts by compensating for this excess KBr. The amount of replenisher is calculated by using the following formula:

$$\frac{\text{1 liter (original solution)}}{\text{0.8 (original KBr)}} = \frac{\text{X (water needed)}}{\text{2.17 (exhausted solution KBr)}}$$

$0.8x = 2.17$

$8x = 21.7$

$x = 2.71\ H_2O$

Since the KBr is in solution, 1 gram/1 must be subtracted as follows: 2.71 − 1 = 1.71. Thus, we must add 1.71 liters of water for each liter of exhausted developer. The exhausted developer has a volume 3.196 liters. To find how much water is to be added, proceed as follows:

$3.196 \times 1.7 = 5.4332$

Thus, 5.4332 liters of water must be added to the exhausted developer to bring the KBr down to the proper strength. All other needed (deficient) chemicals (table 2-2) are added to this water.

The rate of replenishment was determined next. The solution was exhausted by processing 300 sheets of film and 5.433 liters of replenisher were needed. To find the milliliters of replenisher per unit of film, divide 5433 ml by 300 which equals 18.11 ml of replenisher per unit of film (in this case, per sheet).

During the exhaustion test, the first 10 "sensi" strips processed in the fresh solution were used to establish the 3-sigma control. These controls will be the standard when replenishment is used. Controls were established in the following manner (figs. 2-10 through 2-16):

D/Max

Strip	$\overline{X}$	R (Δ D)
4-5	1.765	0.07
6-7	1.855	0.17
8-9	1.84	0.08
10-11	1.825	0.03
12-13	1.83	0.06
	Sum = 9.115	Sum = 0.41

$$\overline{\overline{X}} = \frac{9.115}{5} = 1.82$$

$$\overline{\overline{R}} = \frac{0.41}{5} = 0.082$$

Thus

$$\overline{X} + 1.880 \times \overline{R} = D/max$$

Or

$$1.82 \pm 1.880 \times 0.082 = 1.82 \pm 0.15$$

So

$$D/max = 1.82 + 0.15 = 1.97 \text{ UCL}$$

And

$$D/min = 1.82 - 0.15 = 1.67 \text{ LCL}$$

NOTE: The value 1.880 is obtained from 3-sigma control limits for $\overline{X}$ and R charts. (See AFM 52–2, Vol. 1, or other sources of statistical tables.)

Following the above calculations, the range controls were calculated using D/max as an example. Refer to figure 2–11 and calculate as follows:

$$3.267 \times \overline{R} = 3.267 \times 0.082 = 0.27 \text{ UCL}$$

Where

$$\text{average range } \overline{R} = 0.08$$

Thus

UCL = 0.27 and
LCL = 0.00

NOTE: See previous AFM 52–2, Vol. 1, reference for the value 3.267.

After replenishment and rate of addition were found, a new process was set up. Another 4-liter portion of the original 16-liter batch was set up. Also, on hand was a prepared batch of replenisher that had a pH of 9.87, a BI of 5.93, and a TA of 1.02.

Processing started with 18 sheets of film being developed. After each group of 18 sheets had been processed, 325 ml of replenisher were added. This was done using a long-stem funnel so that the replenisher reached the bottom of the tank, forcing overflow of the used developer.

A 50-ml sample was taken after each replenishment and its pH was taken. Figure 2-17 shows a running graph of pH readings during processing. The pH was somewhat low as

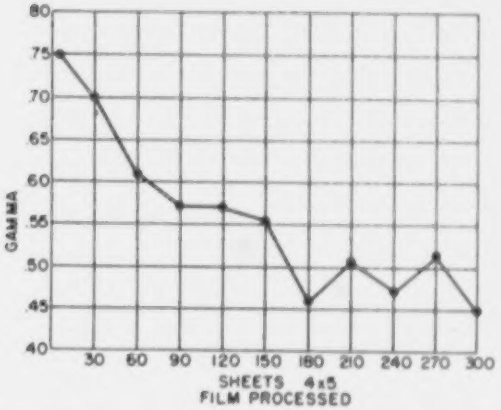

Figure 2–10. Gamma vs. sheets, no replenishment to exhaustion, 68°F.

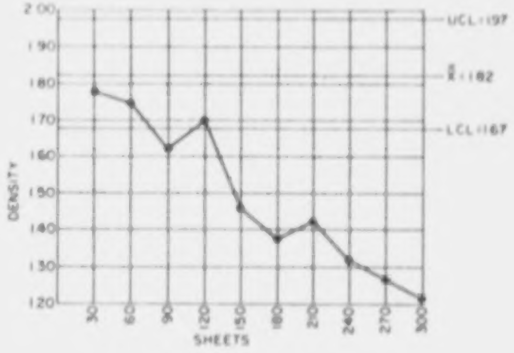

Figure 2-11. D/max, beginning to exhaustion.

you can see. Therefore, at the end of processing the sixth batch of film, a 5-percent sodium hydroxide solution was added to raise the pH from 8.72 to 9.73. The pH after the seventh batch of film was 9.72 and appeared to be holding.

Between the seventh and eighth batches of film, the sigma limits were changed since it was found that the first controls were not applicable. The new control limits were established from samples taken from batch 8 through batch 19. The resulting controls that were calculated from these samples fit the process, and control was retained from the remainder of the project. The first controls were determined from the average of the differences between the two strips in each process, and this did not produce correct control limits. The new controls were determined by averaging a selection of good samples and determining a normal. This resulted in a normal (or acceptable) D/min, D/mid, and D/max. Thus, new 3-sigma limits were established (See figs. 2-18 through 2-21).

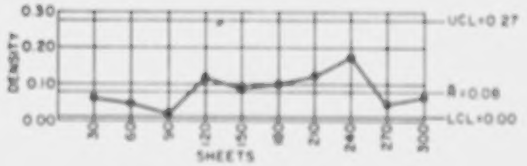

Figure 2-12. Ranges, density, difference with batches.

Refer to table 2-3 for the end result of the analysis. By studying the various parameters listed, you will note that the replenisher rate apparently should be recalculated and an adjustment made of its constituent chemicals.

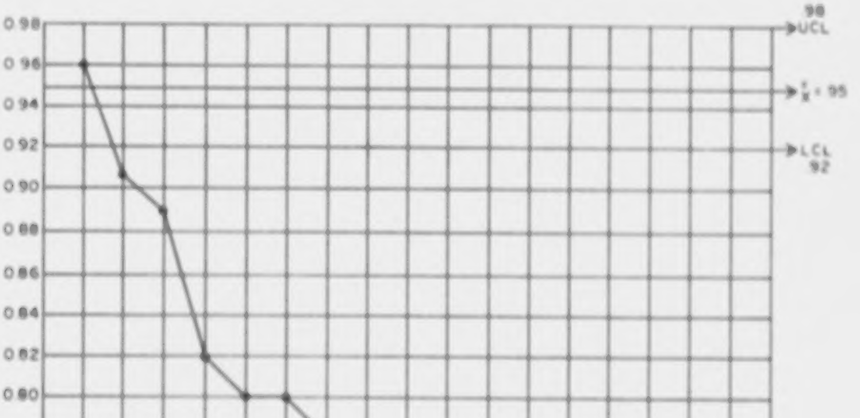

Figure 2-13. D/mid-batch, beginning to exhaustion.

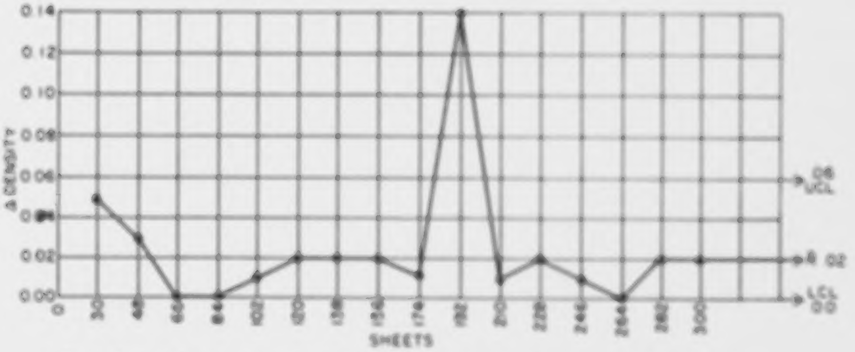

Figure 2-14. D/mid-batch, beginning to exhaustion, density differences within batches.

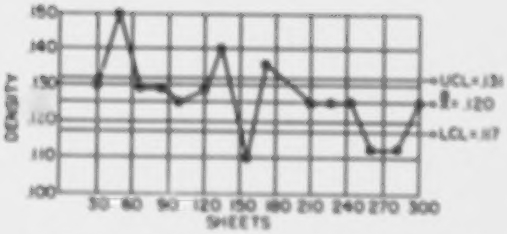

Figure 2-15. D/min progression, beginning to exhaustion.

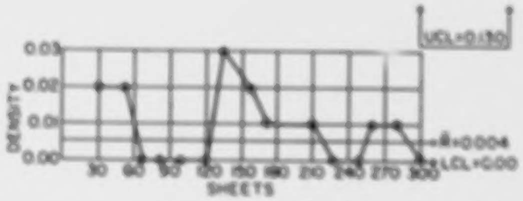

Figure 2-16. Ranges, density difference of two strips, individual batches.

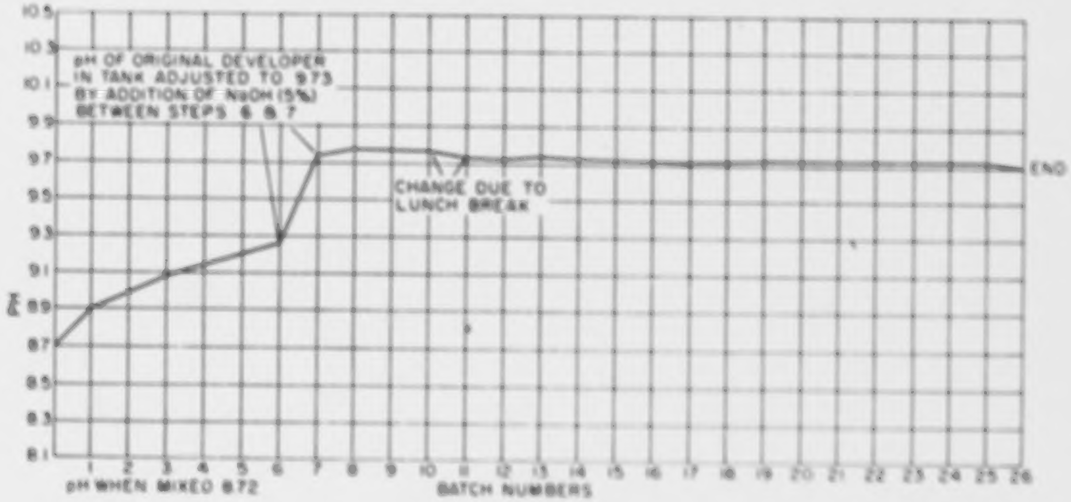

Figure 2-17. The pH of each batch of film processed.

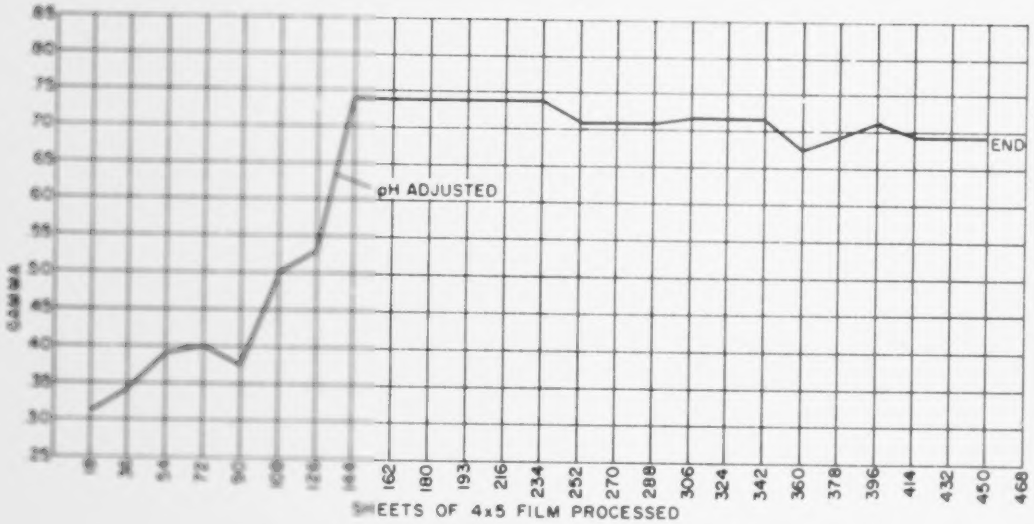

Figure 2-18. Gamma vs. sheets in one solution, with replenishment, 68°F.

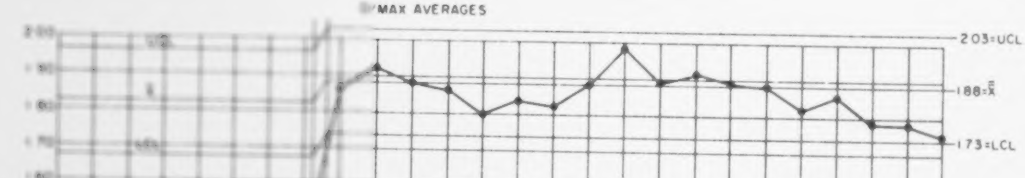

Figure 2-19. D/max averages and ranges.

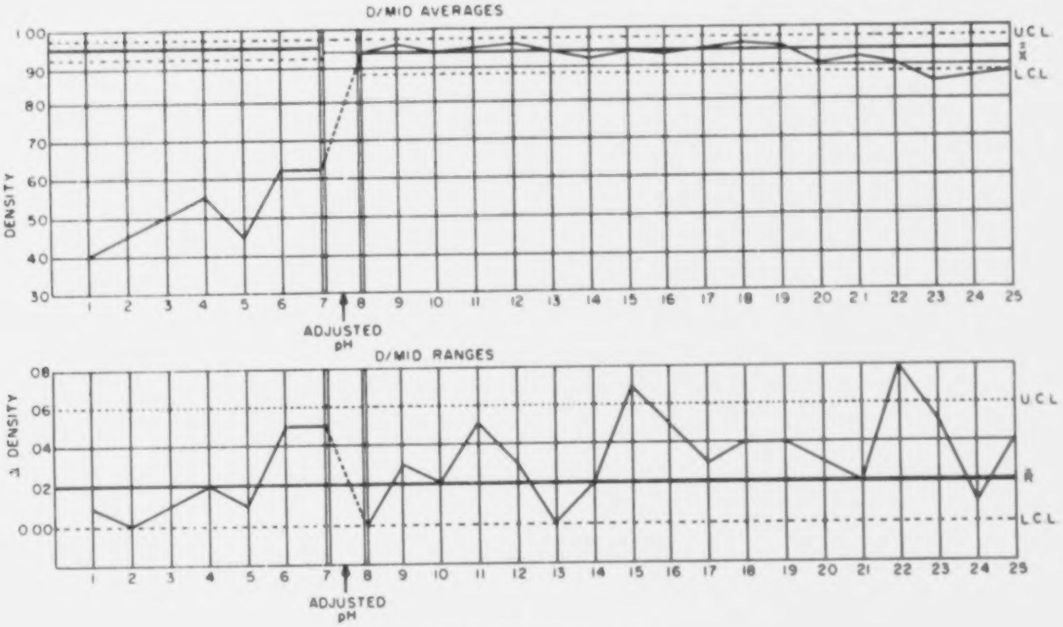

Figure 2–20. D/mid averages and ranges.

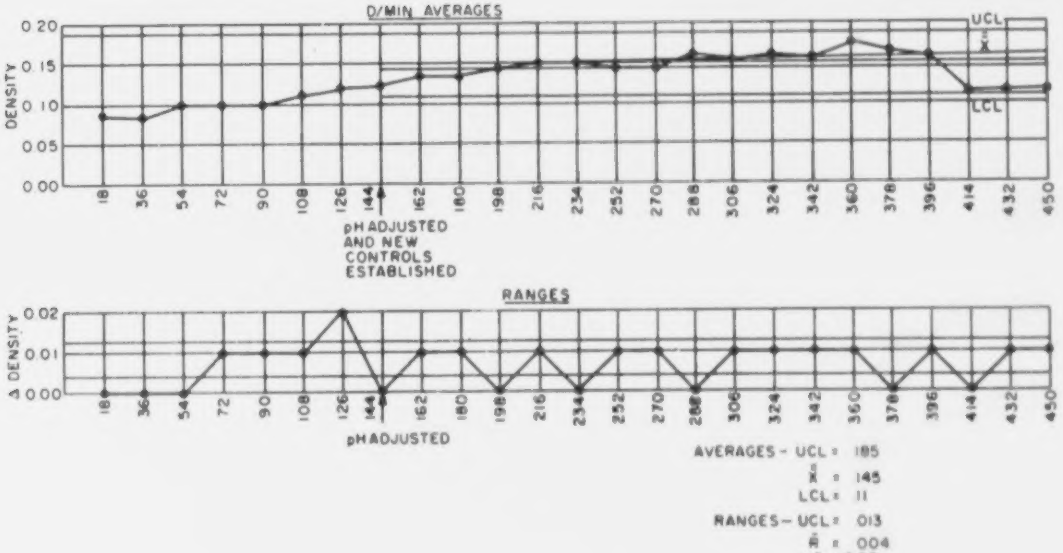

Figure 2–21. D/min averages and ranges.

TABLE 2-3
CHEMICAL ANALYSIS OF REPLENISHER AND REPLENISHED DEVELOPER, g/1

CHEMICAL	AS MIXED	FIRST ANALYSIS	AFTER 288 SHEETS	AT END OF PROJECT
Metol	1.82	1.89	1.59	1.59
HQ	3.16	3.18	2.83	2.88
CO_3	10.0	9.92	8.12	7.53
SO_3	44.4	44.11	42.72	42.45
KBr	–	–	0.93	1.12
pH	–	9.87	9.72	9.70
BI	–	5.93	–	5.10
TA	–	1.02	–	1.97

Exercises (A69):

1. In establishing a replenisher formula, the first step is to quantitatively analyze the fresh developer. Why is this done?

2. You are going to determine a replenisher. How will you establish the proper development time to be used as a standard?

3. You have determined a developer replenishment formula and the rate of replenishment. Do you need to conduct further tests?

Bibliography

Books

Chemical Control Procedures for Black and White Film Processing. Rochester, N.Y.: Motion Picture Film Department, Eastman Kodak Company.

Control Techniques in Film Processing. New York: The Society of Motion Picture and Television Engineers.

Rickmers and Todd, *Statistics: An Introduction*. New York: McGraw-Hill Book Company, Inc.

APPENDIX

Common Logarithm Tables

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

APPENDIX

Common Logarithm Tables

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Answers for Exercises

CHAPTER 1

Reference:

A01 − 1. Random events have a tendency to occur within certain flexible regions of occurrence for a predictable percentage of time.

A02 − 1. No, such events are said to be mutually exclusive.

A02 − 2. Since there are 52 possible results, only one of which is favorable, the probability is therefore 1:52 or about 0.019 percent.

A02 − 3. Since there are six faces and 6 possible results, only one of which is favorable, the probability is therefore 1:6 or 0.17 percent.

A02 − 4. The probability of drawing an ace from a deck of cards is $4/52 = 1/13$. The probability of drawing a king is $4/52 = 1/13$. The probability of drawing either an ace or a king in a single draw is $1/13 + 1/13 = 2/13$. Since both ace and king cannot be drawn in a single draw, they are mutually exclusive.

A02 − 5. Deductive reasoning.

A02 − 6. If H denotes heads and T denotes tails, the two tosses can lead to four conditions HH, HT, TH and TT, all equally likely. Only the last three are favorable to the event. Therefore $p = 3/4 = .075$.

A02 − 7. Because deductive reasoning lets you know the probable outcome before an event takes place, the probability is said to be *a priori*, and the classical definition deals only with that kind of condition.

A03 − 1. A frequency or a posteriori probability is the kind of reasoning that derives propositions from the observation of facts, or by generalizations from facts arriving at principles.

A03 − 2. They are derived empirically or a posteriori.

A04 − 1. In statistics, the complete collection of a related group of individual items, objects, or events is called a population, while a sample is some portion of the population. The sample should be such that is represents the population; otherwise, it is not valid.

A04 − 2. The exact way in which you do this is unimportant. What is important is that you use some method, such as closing your eyes and touching table 1–2 with a pencil point or other object to select the particular series of random numbers that will comprise each sample. Of course, you must number each roll of film consecutively from 00 to 99 inclusive. You may find that the same number will occur more than once. That sample means that you will be taking more than one sample from the same roll.

A04 − 3. The sample must be taken at random, it must be large enough to represent the population, and it must be taken in such a way that every individual has an equal chance of being chosen.

A05 − 1. The requirements of a good sample are (1) representative, (2) without bias, (3) proper size, and (4) taken at random.

A05 − 2. Pure chance.

A06 − 1. To provide adequate protection to the producer and the consumer.

A06 − 2. The two parties involved in an acceptance sampling situation look for an inspection procedure that never rejects a good lot or never accepts a bad lot.

A06 − 3. The producer has to accept the possibility that under a sampling plan some of his good lots are going to be falsely rejected.

A06 − 4. The consumer has to accept the possibility that he is going to make mistakes of sometimes accepting bad lots.

A06 − 5. The purpose of the sampling procedure is to differentiate between good and bad lots and determine the risks that the plan will make mistakes of rejecting a good lot or accepting a bad one.

A07 − 1. In ascending order of magnitude, the array is: 16, 18, 22, 24, 27, 30, 33, 36, 38, 40, 48, 49. In descending order, the array is: 49, 48, 40, 38, 36, 33, 30, 27, 24, 22, 18, 16. Since the largest number is 49, and the smallest number is 16, the range is $49 - 16 = 33$.

A08 − 1. The best way to approach this problem is to construct an array, but instead of an ordinary arrangement in order of magnitude, try combining the things you know about frequency distribution and construct an array against an arrangement of class intervals. The table below, called an entry table, is an excellent first step for this problem.

50 - 54	53
55 - 60	59, 57
60 - 64	60, 62, 63, 62, 62, 61, 60, 61, 62, 63, 60
65 - 69	68, 68, 67, 65, 65, 67, 65, 68, 69, 66
70 - 74	73, 73, 71, 73, 72, 74, 73, 71, 71 , 74, 72, 74
75 - 79	79, 75, 76, 75, 76, 75, 77, 76, 78, 75, 76, 78, 79, 78, 75, 79, 75, 78, 77, 75, 78
80 - 84	82, 84, 81, 80, 83, 82
85 - 89	88, 85, 88, 86, 85, 88, 85, 89, 87
90 - 94	93, 93, 90, 94
95 - 99	97, 96, 95, 95

Now construct your array within each class interval:

50 - 54	53
55 - 59	57, 59
60 - 64	60, 60, 60, 61, 61, 62, 62, 62, 62, 63, 63
65 - 69	65, 65, 65, 66, 67, 67, 68, 68, 68, 69
70 - 74	71, 71, 71, 72, 72, 73, 73, 73, 73, 74, 74, 74
75 - 79	75, 75, 75, 75, 75, 75, 75, 76, 76, 76, 76, 77, 77, 78, 78, 78, 78, 78, 79, 79, 79
80 - 84	80, 81, 82, 82, 83, 84
85 - 89	85, 85, 85, 86, 87, 88, 88, 88, 89
90 - 94	90, 93, 93, 94
95 - 99	95, 95, 96, 97

A08 − 2. a. The greatest weight is 176 pounds and the least weight is 119 pounds. Therefore, the range is $176 - 119 = 57$ pounds. Although a number of class interval sizes would do very well for this situation, it is probably most convenient to use a class interval size of 5 pounds. Also, it would be convenient to use as cell midpoints, 120, 125, 130, 135, . . ., pounds, which would give you class intervals of 118–122, 123–127, 128–132, ... The class boundaries, then, would be: 117.5, 122.5, 127.5, . . ., which do not coincide with observed data. Using the format shown here, tally the frequencies of the weights as they occur in the various cells.

b.

Weight (lbs)	Tally	Frequency
118 - 122	I	1
123 - 127	II	2
128 - 132	II	2
133 - 137	IIII	4
138 - 142	IIIII I	6
143 - 147	IIIII III	8
148 - 152	IIIII	5
153 - 157	IIII	4
158 - 162	II	2
163 - 167	III	3
168 - 172	I	1
173 - 177	II	2
		Total 40

A08 − 3. a. The range of your data is $7.44 - 5.18 = 2.26$ cm. For a minimum of five class intervals, the class interval size is $2.26 \div 5 = 0.45$ approximately. For a maximum of 20 class intervals, the class interval size is $2.26 \div 20 = 0.11$ approximately. However, it is generally better to use a class interval size lying somewhere between the maximum and the minimum. In this case, you might choose a class interval of 0.20, 0.30, or 0.40. If you chose 0.20, your set of class intervals would be as follows:

5.10 - 5.29
5.30 - 5.49
5.50 - 5.69
5.70 - 5.89
5.90 - 6.09
6.10 - 6.29
6.30 - 6.49
6.50 - 6.69
6.70 - 6.89
6.90 - 7.09
7.10 - 7.29
7.30 - 7.49

If you chose a class interval size of 0.30, your set would be as follows:

5.10 - 5.39
5.40 - 5.69
5.70 - 5.99
6.00 - 6.29
6.30 - 6.59
6.60 - 6.89
6.90 - 7.19
7.20 - 7.49

If you selected 0.40 for your class interval size, you would have:

5.10 - 5.49
5.50 - 5.89
5.90 - 6.29
6.30 - 6.69
6.70 - 7.09
7.10 - 7.49

In this solution, we set the lower limit of the first class at 5.10; however, you could have started with 5.15, in which case the first class interval of 0.20 size would have been written 5.15 - 5.34, and so forth.

b. The class boundaries for the 0.20 class interval would be 5.095 – 5.295, 5.295 – 5.495, 5.495 – 5.695, . . ., 7.195 – 7.495. The class boundaries for the 0.40 class interval size would be: 5.095 – 5.495, 5.495 – 5.795, 5.795 – 6.095, . . ., 7.095 – 7.495. These class boundaries cannot coincide with observed measurements and are therefore quite suitable.

c. The cell midpoints for the 0.20 class interval size would be: 5.195 – 5.395, . . ., 7.395. For this 0.30 size, the midpoints are: 5.425, 5.545, . . ., 7.345. For the 0.40 size, the midpoints are: 5.295, 6.695, . . ., 7.295. Unfortunately, these cell midpoints cannot coincide with observed data and this is a disadvantage. However, there will be many cases where this condition will exist.

A09 – 1. a. Construct a table as follows, and calculate percentages by dividing the frequency of each class by the total frequency.

Weight (lbs)	Relative Frequency (%)
118 - 122	2.5
123 - 127	5.0
128 - 132	5.0
133 - 137	10.0
138 - 142	15.0
143 - 147	20.0
148 - 152	12.5
153 - 157	10.0
158 - 162	5.0
163 - 167	7.5
168 - 172	2.5
173 - 177	5.0
	Total 100.0%

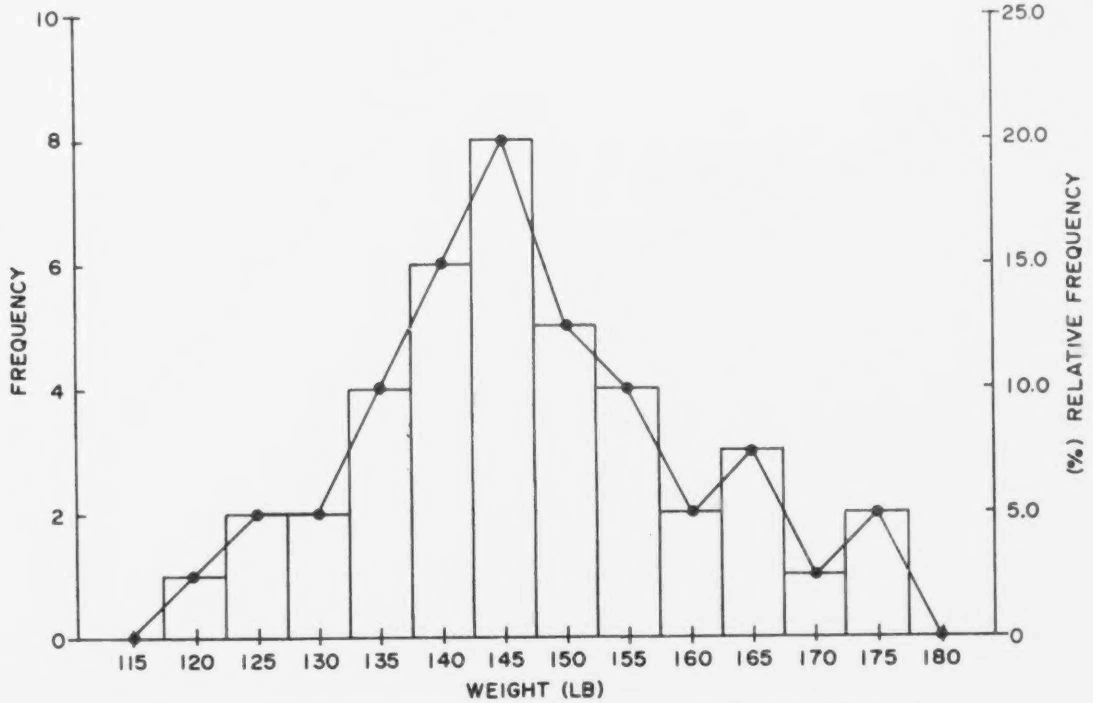

Figure A–1. Frequency and relative frequency histogram and polygon of airmen (objective A09, exercise 1).

b. and c.

A10 – 1. a. and b. Tabulate your distribution as shown in the following table:

Weight (lb)	Cumulative Frequency	Percentage Cumulative Frequency
Less than 118	0	.0
Less than 123	1	2.5
Less than 128	3	7.5
Less than 133	5	12.5
Less than 138	9	22.5
Less than 143	15	37.5
Less than 148	23	57.5
Less than 153	28	70.0
Less than 158	32	80.0
Less than 163	34	85.0
Less than 168	37	92.5
Less than 173	38	95.0
Less than 178	40	100.0

You obtain each entry in column 2 by adding the successive entries in your frequency distribution. Thus, 1 + 2 = 3, 3 + 2, = 5, 5 + 4 = 9, . . ., 38 + 2 = 40. Calculate the percentage cumulative frequency for each entry in column 3 by dividing each successive entry in column 2 by the total frequency 40 and multiplying by 100.

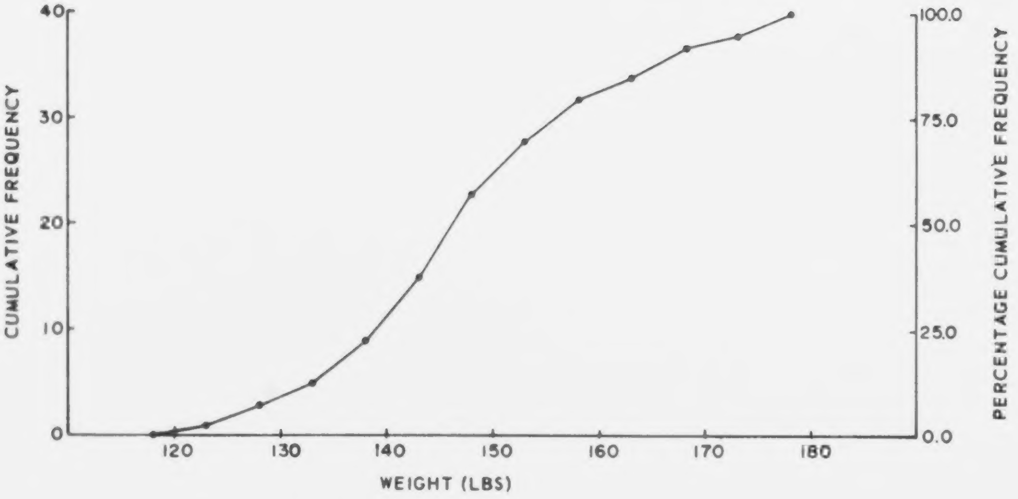

Figure A-2. Ogive and percentage of ogive of the cumulative frequency of weights of airmen (objective A10, exercise 1).

b. and d. The ogive and the pecentage ogive are shown in figure A-2. Arrange your graph to show the cumulative frequency on the vertical scale on the left, and the percentage cumulative frequency on the vertical scale on the right.

A10 – 2. a. and b. Tabulate your "or more" distribution as shown in the following table:

Weight (lbs)	"Or More" Cumulative Frequency	Percentage Cumulative Frequency
118 or more	40	100.0
123	39	97.5
128	37	92.5
133	35	87.5
138	31	77.5
143	25	62.5
148	17	42.5
153	12	30.0
158	8	20.0
163	6	7.5
173	2	5.0
178	0	0.0

You can obtain the entries for column 2 by starting at the bottom of your frequency distribution table and adding, or by starting at the top and subtracting each successive entry.

c. Construct your "or more" ogive in the same manner you constructed your cumulative frequency polygon in exercise A10-1. The result should resemble figure A–3.

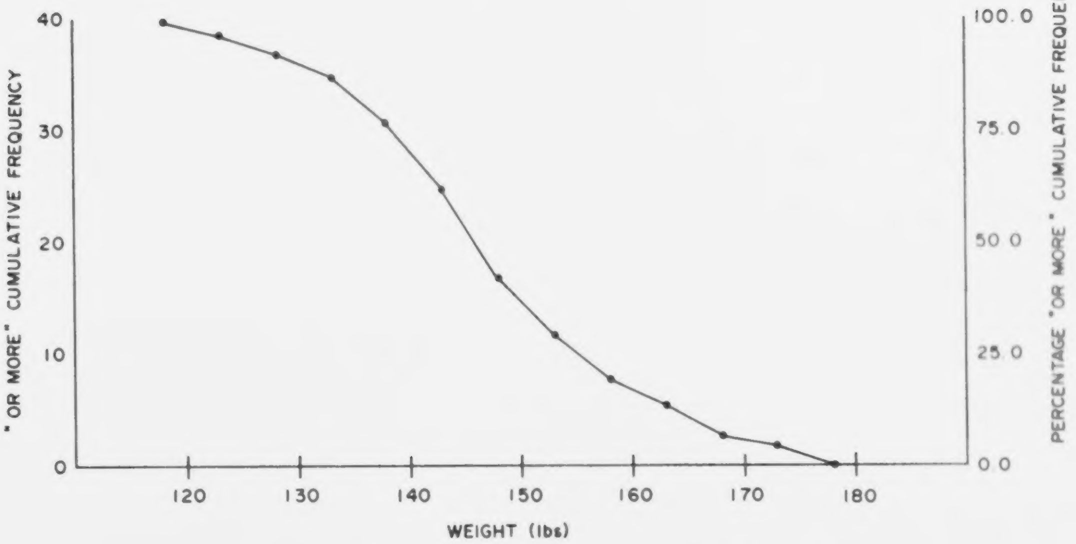

Figure A–3. "Or more" cumulative frequency ogive (objective A10, exercise 2).

A11 – 1. The eight representative shapes of the frequency curves are: (1) symmetrical or bell-shaped, (2) skewed to the right (positive skewness), (3) skewed to the left (negative skewness), (4) J-shaped, (5) reverse J-shaped, (6) U-shaped, (7) bimodal, and (8) multimodal.

A11 – 2. (1) The symmetrical or bell-shaped curve is produced because the observations extending equally on either side of a control maximum have the same frequency.

(2) The skewed to the right curve has a longer tail to the right of the maximum.

(3) The skewed to the left curve has a longer tail to the left of the maximum.

(4) In the J-shape and reverse J-shaped curve, the maximum occurs at one end.

(5) When the maximum occurs at both ends, the curve is U-shaped.

(6) When the curve has two maxima, the curve is bimodal.

(7) If the curve has three or more maxima, it is called trimodal or multimodal.

A12 – 1. a. $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8$

b. $(Y_1 - 2)^3 + (Y_2 - 2)^3 + (Y_3 - 2)^3 + (Y_4 - 2)^3$

c. $a + a + a + \ldots + a = Na$

d. $f_1X_1 + f_2X_2 + f_3X_3 + f_4X_4 + f_5X_5 + f_6X_6$

e. $(X_1 - a) + (X_2 - a) + (X_3 - a) + (X_4 - a) + (X_5 - a)$
$= X_1 + X_2 + X_3 + X_4 + X_5 - 5a$

A12 – 2. a. $\sum_{j=1}^{20} X_j$

b. $\sum_{j=1}^{10} (X_j - Y_j)$

c. $\sum_{j=1}^{8} f_j X_j^2$

d. $\sum_{j=1}^{N} a_j b_j$

e. $\sum_{j=1}^{6} f_j X_j Y_j$

A13 – 1. $\bar{X} = \frac{\Sigma X}{N} = \frac{80 + 88 + 79 + 93 + 90}{5} = 86$

A13 – 2. $\bar{X} = \frac{\Sigma X}{N} = \frac{5+4+6+2+5+5+7+8+7+4+7+6+9+8+5+3+5}{17} = \frac{96}{17} = 5.6$

If you saw this as a set of numbers containing five 5's, three 7's, two 4's, two 6's, and two 8's, you might have done this:

$$\bar{X} = \frac{\Sigma fX}{\Sigma f} = \frac{\Sigma fX}{N} =$$

$$\frac{(5)(5)+(3)(7)+(2)(4)+(2)(6)+(2)(8)+(1)(2)+(1)(3)+(1)(9)}{5+3+2+2+2+1+1+1} = \frac{96}{17} = 5.65$$

The second method is the one you will use most frequently as you use statistical control procedures. Train yourself to see combinations of numbers and use reliable shortcuts.

A13 - 3. Perhaps the best way to approach this problem is to set down your formula, decide what is needed to substitute into it, and expand your frequency distribution to present the needed information in an organized fashion. Your expanded table should appear generally as follows:

Height (Inches)	Cell Midpoint	Frequency	fx
60 - 62	61	5	305
63 - 65	64	18	1152
66 - 68	67	42	2814
69 - 71	70	27	1890
72 - 74	73	8	584
	N =	f =	fx = 6745

In the expanded table, you show the cell midpoints which are the mean heights in the cells. (All items in a cell are considered as being equal to the cell midpoint.) You also show in column 4 the produce of the cell midpoints and the cell frequencies and have shown the sum of the fx at the end of the column. Now, substituting the information from your table into the formula

$\bar{X} = \frac{\Sigma fx}{\Sigma f} = \frac{\Sigma fx}{N}$, you have:

$\bar{X} = \frac{6745}{100} = 67.45$ inches.

A14 - 1. Arrange the gammas in an array thus: .79, .81, .82, .84, .85, .88. Since there are two middle values .82 and .84, the median is the arithmetic mean of these two values:

$$\frac{.84 + .84}{2} = .83$$

A14 - 2. Arrange the gammas in an array thus: .79, .80, .81, .82, .84, .85, .88. Since there is an odd number of gammas with only one middle item in the array, with three above and three below, the median item is .82.

A15 - 1. (a) Arrange the numbers in an array: 2, 3, 3, 4, 4, 5, 5, 5, 6, 7. The mode is 5, the number appearing most frequency.
(b) The mode does not exist in this set of numbers.

A16 - 1. They coincide.

A16 - 2. Mean − mode = 3 (mean − median).

A17 - 1. Using a table of logarithms, calculate the geometric mean as follows:

$$G = \sqrt[7]{(3)(5)(6)(6)(7)(10)(12)} = \sqrt[7]{453{,}600}$$

$$\log G = \frac{1}{7} \log 453{,}600 = \frac{1}{7}(5.6571)$$

$$\log G = 0.8081$$

$$G = 6.43 \text{ (to the nearest hundredth)}$$

If you calculated as follows, you are also correct:

$$\text{Log } G = \frac{1}{7}(\log 3 + \log 5 + \log 6 + \log 6 + \log 7 + \log 10 + \log 12)$$

$$= \frac{1}{7}(0.4771 + 0.6990 + 0.7782 + 0.7782 + 0.8451 + 1.00 + 1.0792)$$

$$\text{Log } G = 0.8081$$

$$G = 6.43$$

A18 - 1. Since the harmonic mean is the reciprocal of the arithmetic mean of the reciprocals of the numbers then

$$\frac{1}{H} = \frac{1}{N}\left(\Sigma\frac{1}{X}\right) = \frac{1}{7} + \left(\frac{1}{3} + \frac{1}{5} + \frac{1}{6} + \frac{1}{6} + \frac{1}{7} + \frac{1}{10} + \frac{1}{12}\right)$$

$$= \frac{1}{7} \quad \frac{(140 + 84 + 70 + 70 + 60 + 42 + 35)}{420}$$

$$\frac{1}{H} = \frac{1}{7}\left(\frac{501}{420}\right) = \frac{501}{2940}$$

$$H = \frac{2940}{501} - 5.87$$

You may find it convenient to express the fractions in decimal form first. Then the solution would be

$$\frac{1}{H} = \frac{1}{7}(0.33 + 0.200 + 0.1667 + 0.1667 + 0.1429 + 1.000 + 0.0853) = \frac{1}{7}(1.1929)$$

$$H = 7/1.1929 - 5.87$$

A19 - 1. The geometric mean of a set of numbers $X_1, X_2, \ldots, X_N N$ is less than or equal to their arithmetic mean but is greater than or equal to their harmonic mean.

A19 - 2. The set 3, 4, 8 has an arithmetic mean of 4.67, a geometric mean of 4, and a harmonic mean of 3.43.

A20 − 1. $\text{RMS} = \sqrt{\dfrac{3^2 + 5^2 + 6^2 + 6^2 + 7^2 + 10^2 + 12^2}{7}}$

$= \sqrt{57} = 7.55$

A21 − 1. a. The first quartile, Q_1, is obtained by counting N/r = 120/4 = 30 of the cases beginning with the lowest class. This includes all the cases in the first three classes plus 15 cases from the 4th class (30 cases). Using a method of linear interpolation, we have

$$Q^1 = 59.5 + \frac{24}{21}(1) = 60.64 \text{ rounded off } 61$$

Notice that in the interpolation, we took the lower cell boundary of the class containing the quartile we are seeking and added to it the fraction of cases to be included, multiplied by the class size. We now have $Q_1 = 61$. The second quartile obtained by counting 2N/4 = N/2 = 120/2 = 60. Referring to our table, we find that Q_2 is found in the 5th class. By interpolation, we have

$$Q_2 = 69.5 + \frac{24}{43}(1) = 70 \text{ (rounded off)}$$

We now have

$Q_1 = 61$
$Q_2 = 70$
$Q_3 = 83$

b. We see from this that 25 percent of the airmen scored 61 or lower (or 75 percent scored 61 or higher), 50 percent scored 70 or lower (or 50 percent scored 70 or higher), and 75 percent scored 83 or lower (or 25 percent scored 83 or higher).

A22 − 1. The various measures of dispersion or variation are range, mean deviation, quartile deviation, and standard deviation.

A23 − 1. The range of both sets of numbers is the same since range = largest number − smallest number = 18 − 3 = 15.

A23 − 2. The dispersions of the two sets of numbers can be seen when you arrange them in arrays, thus

a. 3, 5, 6, 7, 10, 12, 15, 18.
b. 3, 8, 8, 8, 9, 9, 9, 18.

It is plain that there is much more dispersion or variation in "a" than in "b." This indicates that while the range describes the limits of a set of data, it tells us nothing about the individual items that make up the set.

A24 − 1. For set a.

Arithmetic mean $\bar{X} = \dfrac{6 + 12 + 3 + 7 + 15 + 18 + 10 + 5}{8} =$

$\dfrac{76}{8} = 9.5$

Mean deviation M.D. $= \dfrac{\Sigma|X - \bar{X}|}{N} =$

$$\frac{|6-9.5| + |12-9.5| + |3-9.5| + |7-9.5| + |15-9.5| + |18-9.5| + |10-9.5| + |15-9.5|}{8} =$$

$$\frac{3.5 + 2.5 + 6.5 + 2.5 + 5.5 + 8.5 + 0.5 + 4.5}{8} = \frac{34}{8} = 4.25$$

For set b:

Arithmetic mean $\bar{X} = \dfrac{8 + 8 + 3 + 9 + 8 + 9 + 9 + 8}{8} = \dfrac{62}{8} = 7.75$

Mean deviation M.D. $= \dfrac{\Sigma|X - \bar{X}|}{N} =$

$$\frac{|8-9| + |8-9| + |3-9| + |9-9| + |8-9| + |9-9| + |9-9| + |18-9|}{8} =$$

$$\frac{1 + 1 + 6 + 0 + 1 + 0 + 0 + 9}{8} = \frac{18}{8} = 2.25$$

A25 − 1. Use the data in table 1−3 and apply the equation

$$Q = \frac{Q_3 - Q_1}{2}$$

Find the values for Q_3 and Q_1 as you did in the exercise in objective A21.

Lower quartile $Q_1 = 65.5 + \dfrac{2}{42}(3)$

$= 65.64$ inches

Upper quartile $Q_3 = 68.5 \, \dfrac{10}{27}(3)$

$= 69.61$ inches

$$Q = \frac{69.61 - 65.64}{2} = \frac{3.97}{2} = 1.98 \text{ inches}$$

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50 percent of the cases lie between Q_1 and Q_3 and 50 airmen have heights between 65.64 inches and 69.61 inches. We can consider $\frac{Q_1 + Q_3}{2} = 67.63$ to be the average height of the airmen; therefore, we can reason that 50 percent of the heights are in the range of 67.63 ± 1.98 inches.

A26 – 1. Since each of these sets can be considered as a population, and since the number of individuals is small, we can apply the equation

$$\sigma = \sqrt{\frac{(X - \overline{X})^2}{N}}$$

For set a:

$$\overline{X} = \frac{6 + 12 + 3 + 7 + 15 + 18 + 10 + 5}{8} = \frac{76}{8} = 9.5$$

$$\sigma = \sqrt{\frac{\begin{matrix}(6 - 9.5)^2 + (12 - 9.5)^2 + (3 - 9.5)^2 + \\ (7 - 9.5)^2 + (15 - 9.5)^2 + (18 - 9.5)^2 + \\ (10 - 9.5)^2 + (5 - 9.5)^2\end{matrix}}{8}}$$

$$= \sqrt{23.75} = 4.87$$

For set b:

$$\overline{X} = \frac{8 + 8 + 3 + 9 + 8 + 9 + 9 + 18}{8} = \frac{72}{8} = 9$$

$$\sigma = \sqrt{\frac{\begin{matrix}(8-9)^2 + (8-9)^2 + (3-9)^2 + (9-9)^2 \\ (8-9)^2 + (9-9)^2 + (9-9)^2 + (18-9)^2\end{matrix}}{8}}$$

$$= \sqrt{15} = 3.87$$

A27 – 1. Variance is defined as the sum of the squares of deviations from the arithmetic mean divided by the number of observations.

A27 – 2. Since variance is the same as the standard deviation squared (σ^2), it follows that the standard deviation for set a in objective A23 is 4.87 and variance if 4.87^2 or 23.75; and for set b, the standard deviation is 3.87 and variance is 3.87^2 or 14.98.

A28 – 1. When a distribution is positively skewed, its tail extends to the right; when a distribution is negatively skewed, its tail extends to the left.

A29 – 1. A normal distribution is mesokurtic; a low, flat distribution is platykurtic; and a distribution with a high peak is leptokurtic.

A30 – 1. Two or more events that cannot possibly occur at the same time are said to be mutually exclusive.

A31 – 1. The probability that E_2 will occur provided that E_1 has already occurred is called the conditional probability of E_2 given that E_1 has occurred.

A31 – 2. E_1 and E_2 are said to be independent events if the probability that E_2 will occur is the same regardless of the occurrence or nonoccurrence of E_1.

A31 – 3. Two events are said to be dependent if the occurrence of one is in any way affected by the occurrence or nonoccurrence of the other.

A31 – 4. A compound event where E_1 and E_2 can both occur is: For independent events,

$$Pr(E_1 E_2) = Pr(E_1)Pr(E_2 \mid E_1)$$

For three events, E_1, E_2, E_3, we have:

$$Pr(E_1 E_2 E_3) = Pr(E_1)Pr(E_2 \mid E_1)Pr(E_3 \mid E_1 E_2)$$

The probability of occurrence E_1, E_2 and E_3 is equal to the probability of E_1, multiplied by the probability of E_2, given that E_1 has occurred, multiplied by the probability of E_3, given that both E_1 and E_2 have occurred.

A32 – 1. Discrete probability distributions involve conditions where the variable X can assume a discrete set of values with respect to probability, while continuous probabilities are concerned with cases where the variable X assumes a continuous set of values.

A33 – 1. Combinations are any set of numbers or things grouped together without regard to order, while permutations are sets of numbers or things grouped in sequences of particular order.

A33 – 2. Symbolically, 6 factorial is shown as 6!. Its solution is $6 \cdot 5 \cdot 4 \cdot 3 \cdot 2 \cdot 1 = 720$.

A33 – 3. WXYZ - 4 letters. Taken two at a time, their permutation is

$${}_nP_r = 4P_2 = \frac{4!}{(4-2)!} = \frac{4 \cdot 3 \cdot 2 \cdot 1}{2 \cdot 1} = 4 \cdot 3 = 12$$

A33 – 4. Applying the formula $\frac{n!}{n_1!n_2!}$, the number of permutations of the letters in the word "accumulate" are:

$$\frac{10!}{2!2!2!1!1!1!1!} = \frac{10 \cdot 9 \cdot 8 \cdot 7 \cdot 6 \cdot 5 \cdot 4 \cdot 3 \cdot 2 \cdot 1}{2\ 1\ 2\ 1\ 2\ 1\ 1\ 1\ 1\ 1} =$$

10, 9, 8, 7, 6, 5, 5, 3, = 453,600

A33 – 5. All possible combinations of n items taken r at a time are ${}_nC_r$; $C(n,r)$; Cn, r; or $\binom{n}{r}$ which practically is ${}_nC_r =$

$$\frac{n(n-1)\ldots(n-r+1)}{r!} = \frac{n!}{r!(n-r)!} = \frac{{}_nP_r}{r!}$$

A33 – 6. The letters WXYZ taken two at a time can produce:

$$\frac{4!}{2!(4-2)!} = \frac{4 \cdot 3 \cdot 2 \cdot 1}{2 \cdot 1 \cdot 2 \cdot 1} = 3 \cdot 2 = 6 \text{ combinations}$$

A34 – 1. Since

$$\left(\frac{n}{r}\right) = \frac{n!}{(n-r)!r!}$$

$$\left(\frac{3}{1}\right) = \frac{3!}{(3-1)!1!} = \frac{3 \cdot 2}{2} = 3$$

$$\left(\frac{4}{3}\right) = \frac{4!}{(4-3)!4!} = \frac{4 \cdot 3 \cdot 2}{3 \cdot 2} = 4$$

$$\left(\frac{5}{2}\right) = \frac{5!}{(5-2)!2!} = \frac{5 \cdot 4 \cdot 3 \cdot 2}{3 \cdot 2 \cdot 2} = 10$$

$$\left(\frac{6}{3}\right) = \frac{6!}{(6-3)!3!} = \frac{6 \cdot 5 \cdot 4 \cdot 3 \cdot 2}{3 \cdot 2 \cdot 3 \cdot 2} = 20$$

A34 – 2. The probability of getting 3 heads in 8 tosses of a coin is calculated:

$$8C_3 \left(\frac{1}{2}\right)^3 \left(\frac{1}{2}\right)^{8-3} = \frac{8!}{2!5!} \left(\frac{1}{2}\right)^8$$

$$= \frac{8 \cdot 7 \cdot 6 \cdot 5 \cdot 4 \cdot 3 \cdot 2}{2 \cdot 5 \cdot 4 \cdot 3 \cdot 2} \left(\frac{1}{256}\right) = \frac{168}{256} = \frac{21}{32}$$

A35 – 1. μ (or $\overline{X}$) = the mean, σ = standard deviation, π = 3.14159, and e = 2.71828 (the base of natural or Napierian logarithms).

A35 – 2. a. $Z = \frac{X - \mu}{\sigma} = \frac{70 - 82}{10} = -1.2$

b. $Z = \frac{X - \mu}{\sigma} = \frac{93 - 82}{10} = 1.1$

c. $Z = \frac{X - \mu}{\sigma} = \frac{82 - 82}{10} = 0$

A35 – 3. The grades corresponding to the standard scores:

a. $X = \mu + Z = 82 + (-1)(10) = 82 - 10 = 72$

b. $X = \mu + Z = 82 + (1.6)(10) = 82 + 16 = 98$

A36 – 1. Charts for variables are used to record measured quality characteristics such as dimension in some unit, values for various film characteristics, and similar measurements.

A36 – 2. Imagery production specialists are most likely to use variables control charts for averages ($\overline{X}$), and for ranges (R).

A36 – 3. Control charts for attributes are used to record defects in a product.

A37 – 1. The first step is to decide what measurement is to be made and how the samples are to be taken. The next step is to list the observed data in a chart or an array. Then plot the values on a control chart and connect the plotted points. You must label your charts $\bar{X}$ for averages and R for ranges.

A37 – 2. (1) You want to know that the product you are producing is satisfactory and you want some basis for deciding what action, if any, should be taken; (2) when a sample seems to be unsatisfactory.

A38 – 1. An R chart shows the variation that is present within the samples.

A38 – 2. Apply the formula $UCL^R = D_4\bar{R}$ and $LCL_r + D_3\bar{R}$ to the table for determining control limits.

A38 – 3. On range charts, high plots indicate large "within-sample" variability.

A39 – 1. Since $\bar{X}$ charts show "between-sample" variations while concealing the "within-sample" variations pointed out by R charts, you need both for complete process control.

A40 – 1. Statistical tables are classified generally as general-purpose and special-purpose tables.

A40 – 2. General-purpose statistical tables are used mainly to present original data from which special-purpose tables may be constructed.

A40 – 3. Special-purpose statistical tables are used to present particular aspects of the data derived from general-purpose tables.

A41 – 1. Statistical tests to learn whether significant changes have taken place in a process are called tests of significance or tests of hypothesis.

A42 – 1. The hypothesis that no difference exists between elements being tested is called the null hypothesis.

A43 – 1. A type I, or alpha (α), error is the error you make when you reject a hypothesis you should have accepted. A type II, or beta (β), error is the error you make when you accept a hypothesis you should have rejected.

A44 – 1. An α risk to the 0.05 significance level means that you are taking a 5-percent chance of rejecting a hypothesis you should have accepted.

A45 – 1. When conducting significance tests involving normal distributions, the z score is the test statistic used.

A46 – 1. The test statistics for hypothesis testing sample versus population where σ is known is the z score.

A47 – 1. When hypothesis testing, sample versus population, σ unknown, use the t score as the test statistic.

A47 – 2. You reject the null hypothesis because your test tells you that a significant difference is present in your process. You must make a decision because of this. However, the decision cannot be "cut and dried." You must consider other factors affecting your process, including the size of the sample used in the test. If you feel that more can be learned by repeating the test using larger samples, do so. If you feel that the test is adequate, then take the necessary steps to rectify the differences in your processes.

A48 – 1. In analysis of variance, you compute significance by classifying and cross-classifying data and applying the correct formula.

A48 – 2. When conducting an analysis of variance, the following 10 steps should be pursued: (1) present the data, (2) determine your objective, (3) design the model, (4) state the hypothesis, (5) define the nomenclature, (6) perform your calculations, (7) determine the degree of freedom, (8) prepare an ANOVA table, (9) apply the F test, and (10) draw your conclusions.

A49 – 1. The formula $\frac{T^2}{N}$ tells you to square the grand total of the row and column values and divide the number of individuals making up the data. This gives you a correction factor.

A49 – 2. The symbol T_j represents the total for each column in your table.

A49 – 3. The equation $Q_c = \Sigma\frac{T_j^2}{r} - \frac{T^2}{N}$ gives you the sum of the squares for columns. It tells you to square the column totals, add the squares, divide the sum by the number of rows, and subtract the correction factor.

A49 – 4. The equation $Q_T = \Sigma X^2 = \frac{T^2}{N}$ gives you the total sum of squares. To solve it, square all the individuals, add the squares, and subtract the correction factor from the sum.

A49 – 5. To find the residual sum of squares, (Q_o), subtract the column sum of squares from the total sum of the squares. Thus $Q_o = Q_T - Q_c$.

A50 – 1. A two-factor analysis of variance treats one more variable than does the single-factor analysis. Therefore, the two-factor test will require two null hypotheses and computation for Qr, the sum of squares for rows which contain the second variable.

A50 – 2. Since the residual sum of squares is what is left after subtracting all other sums of squares from the total sum of squared, you find the residual sum of squares for a two-factor test by applying the equation $Q_o = Q_T - (Q_c + Q_r)$.

A50 – 3. In a two-factor test, find degrees of freedom by applying the following equations;

df for $Q_T = N - 1$
df for $Q_c = C - 1$
df for $Q_r = r - 1$
df for $Q_o = (C-1)(r-1)$ or $(N-1) - (c-1+r-1)$

A51 – 1. "Pooling" is a term given to the practice of combining the sum of the squares of a variable with that of residual. You pool when you feel that the variance in a particular variable is not significant.

A51 – 2. Yes. You might establish the policy of never pooling if the residual mean squares are 6 or more; and pooling if the residual mean square is less than 6, provided that the variance ratio for the sums of squares to be pooled is 2 or less.

A52 – 1. It is an analysis that is conducted more than once.

A52 – 2. When more variables are added that might be significant to the variables in, say, a two-factor analysis, you would replicate the analyses, introducing a new variable. An example might be a case where a group of technicians makes a second series of tests.

A53 – 1. To analyze three variables, use a three-factor analysis of variance.

A53 – 2. The data in a three-factor analysis are processed similarly as the data in other tests, but you must prepare three separate two-factor tables called sum-over tables to compare the sums of the squares of the three variables; then you construct three two-factor ANOVA tables in which you analyze the data from the sum-over tables.

A53 – 3. To obtain the A sum of the squares for the A and B ANOVA, take the A (column) totals from the sum-over C table, square them, add them, divide their sum by the total number of cases under each A, and then subtract the correction factor. Follow the same procedure to get the B sums of squares, but use the B (row) totals. Use this procedure with the C values from either the sum-over A or the sum-over B table to get the sums of squares for the B and C ANOVA. (You already have the B sum of squares.) You also have the sums of squares already computed for your A and C ANOVA, and all you have to do is insert them in their proper places.

A53 – 4. Using the variables from exercise 3, you can find the sum of the squares for A and B interaction by applying the equation:

$$\text{SS for A and B} = \frac{\Sigma(\text{A and B})^2}{\text{C units}} - \frac{T^2}{N} - (SS_A + SS_B)$$

where C units = number of units making up the C variable being tested. The equation for B and C interaction, and A and C interaction are:

$$\text{SS for B and C} = \frac{\Sigma(\text{B and C})^2}{\text{A units}} - \frac{T^2}{N} - (SS_B + SS_C)$$

and

$$\text{SS for A and C} = \frac{\Sigma(\text{A and C})^2}{\text{B units}} - \frac{T^2}{N} - (SS_A + SS_C)$$

A53 − 5. Compute the residual sum of squares by adding all the sums of squares for the variables and their interactions and subtracting their sum from the sum of all the squares of your original data minus the correction factors as given in the equations:

$$SS_{Resid} = (\Sigma X^2 - \frac{T^2}{N}) - \Sigma SS$$

A53 − 6. The F test procedure is the same for three-factor analyses as it is for other analyses in that the mean square of each variable and each interaction is computed in turn against the mean square of the residual, and the calculated F's are compared with the Book F's.

A54 − 1. The three prerequisites for a designed experiment are (1) state the objective, (2) describe the experiment, and (3) outline the method to be used to analyze the results of the experiment.

A55 − 1. Experimental error originates in the lack of uniformity of material used in the experiment and in the inherent variability in the techniques employed.

A55 − 2. In a designed experiment, your aim is to test hypotheses pertaining to the universe mean values and to estimate the means and the various components of variance.

A56 − 1. To help you design an experiment, you should prepare a complete checklist.

A57 − 1. A single-factor experiment permits you to test one variable, generally for the purpose of making comparisons between two processes, two materials, two products, and so forth.

A57 − 2. Yes. Unless you knew for certain that there was no difference in the product of the several printers, the printer variability would become confounded with the variability of the film stock being tested.

A57 − 3. The design could be improved if you assigned the film stocks to the printers at random to obtain a completely randomized experiment.

A58 − 1. This would be a two-factor analysis employing a randomized block design.

A59 − 1. A Latin square design.

A59 − 2. For a Latin square design, you must have the same number of operators, machines, and film stocks (to use our example), and may test each film stock only once on each machine and only once by each operator.

A59 − 3. No. These computations are the same for all the tests you have learned about up to now.

A60 − 1. When using triple grouping to reduce errors, the experimental design that results is called a Graeco-Latin square.

CHAPTER 2

A61 − 1. Variability is the range from 0.9 to 1.1 (0.2). Since this range is acceptable, it is also a tolerance because the difference is not significant to the process.

A61 − 2. The curve is said to be skewed.

A61 − 3. The curve has a high peak, and it is said to show kurtosis.

A61 − 4. The process is especially accurate and does not need to be. Therefore, the process is costing too much and the various control procedures may be too tight.

A62 − 1. The test is valid, since specific gravity varies with the temperature of a solution.

A63 − 1. If a test is reliable it means that you will obtain the same measurement each time the test is conducted under an identical set of conditions.

A64 − 1. Standard deviation is a value used to indicate the variation of data from the average (mean) of the data.

A64 − 2. About 32 strips are rejected, or 32 percent.

A64 − 3. The tolerance is over 3 SD, since 100 percent of the values are within the established range. This does not seem to be a critical operation as indicated by a rather high tolerance gamma. For a photoprocessing lab, the range seems excessive and should be reduced.

A64 − 4. Such a change in frequency distribution will not indicate a specific problem, but it will tell you that a problem exists.

A65 − 1. If the limits of variation are within tolerance, there is no cause for worry. Nothing can be kept exactly stable, and results will vary.

A65 − 2. Normally, the vertical axis is marked off in the units of the values of the samples.

A65 − 3. The limits are established from the standard deviation computations.

A65 − 4. As long as the plots stay within the limit, there is no immediate cause for concern, but you should try to correct the cause. If the plots return to the mean, such short term variability is not important.

A65 − 5. One out-of-control plot is probably a chance cause and is essentially ignored. However, six plots are indicating a trend, and the cause should be corrected.

A66 − 1. The information is of value, but the information shows only the variation (if any) of mid-density.

A67 − 1. Information to be used for constructing a range chart will probably include a series of samples and their value taken at a specified time basis. Ranges and averages and averages of averages may also be computed along with standard deviation and control limits.

A67 − 2. Standard deviation, acceptance, fraction defective, percent defective, number defective, defects per unit, demerit, and locally developed special charts are usable, depending on the mission of the laboratory.

A68 − 1. You obtain and graph D/max, D/min, toe density, shoulder density, gamma, and fog level.

A68 − 2. Replynishment simple requires the addition of plain water to the developer.

A69 − 1. Even though you know the amounts of each chemical used in mixing the formula, there may be a slight difference in the analysis amounts.

A69 − 2. Sensitometric strips are processed in the fresh developer at several development times. The correct development time is chosen by determining which strip has the appropriate D/max, D/min, base fog, gamma, and speed.

A69 − 3. You must conduct further tests by using the developer under the conditions followed during the exhaustion tests. Only this time, you replenish the developer at the established rate. Samples can be taken at various points to determine if the used solution is being maintained at original levels. Also, "sensi" strips can be developed at intervals and the results plotted to further validate the replenishment.

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STOP -

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.
2. USE NUMBER 2 PENCIL ONLY.

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

23350 06 01

STATISTICAL QUALITY CONTROL METHODS

Carefully read the following:

DO's:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that item numbers on answer sheet are sequential in each column.
3. Use a medium sharp #2 black lead pencil for marking answer sheet.
4. Write the correct answer in the margin at the left of the item. (When you review for the course examination, you can cover *your* answers with a strip of paper and then check your review answers against your original choices.) After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'Ts:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #2 black lead pencil.

NOTE: **NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE.** In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MULTIPLE CHOICE

Note to Student: Consider all choices carefully and select the *best* answer to each question.

1. (A01) Known occurrences are subject to the laws of
   a. priorities.
   b. possibility.
   c. permutations.
   d. probability.

2. (A01) Select the fields of study that can be used to make reasonable predictions about almost any set of random events.
   a. Priorities and mathematics.
   b. Probability and statistics.
   c. Physics and mathematics.
   d. Priorities and theology.

3. (A02) What is the probability that a 3 or a 4 will turn up in a single toss of a die?
   a. 1/3.
   b. 2/3.
   c. 3/3.
   d. 4/3.

4. (A02) Probabilities determined according to the classical definition are called
   a. mutually exclusive events.
   b. equally likely events.
   c. a posteriori probabilities.
   d. a priori probabilities.

5. (A03) What is the probability of obtaining two tails in two tosses of a coin?
   a. 1/2.
   b. 1/3.
   c. 1/4.
   d. 1/6.

6. (A03) When dealing with statistical methods, all things are subject to
   a. permanence.
   b. randomness.
   c. variability.
   d. regularity.

7. (A04) In the language of statistics, any finite or infinite collection of individual objects or events is called a
   a. population or universe.
   b. distribution.
   c. random distribution.
   d. sampled population.

8. (A04) A sample of a population has certain restrictions. Which of the following is *not* necessary for the sample to be valid?
   a. Randomness.
   b. Size.
   c. Opportunity of being chosen.
   d. Distribution.

9. (A05) When you place numbered slips of paper in a container, draw from the container and place the slips back after each draw, you are using a method of
   a. bias.
   b. randomness.
   c. representation.
   d. accuracy.

10. (A06) Which choice does *not* present an advantage of the sampling inspection procedure?
    a. Costs less.
    b. Provides protection to producer and consumer.
    c. Is a basis for making decisions.
    d. Every item has to be tested.

11. (A06) A figure that measures the risk a supplier takes of having a good lot rejected by a sampling plan is called the
    a. consumer's risk.
    b. producer's risk.
    c. tolerance percent defective.
    d. acceptable level of risk.

12. (A07) The difference between the largest value and smallest value in a frequency distribution is called the
    a. arithmetical mean.
    b. median.
    c. standard deviation.
    d. range.

13. (A07) Data that can assume any value within a certain range is called

a. discrete.
b. continuous.
c. raw.
d. fine.

14. (A08) How do you determine the number of cells to establish when grouping data?

a. Set a policy of using 10 cells.
b. Use the trial and error technique.
c. Use as many cells as possible.
d. Arrange to have 5 units in each class.

15. (A08) To obtain the cell midpoint, you

a. add the upper and lower class limits and divide by 2.
b. subtract the lower class limit from the upper class limit and divide by 2.
c. divide the cell midpoint by 2.
d. use either the upper or lower class limit.

16. (A09) The frequency of a given class divided by the total frequency of all classes is called a

a. partial frequency.
b. proportional frequency.
c. frequency ratio.
d. relative frequency.

17. (A09) The relative frequency of a given class is usually expressed as

a. a whole number.
b. a percentage.
c. a negative number.
d. an integer.

18. (A10) The term "ogive" is used to describe

a. a frequency histogram.
b. a cumulative frequency polygon.
c. a range chart.
d. an attribute control chart.

19. (A11) Observations extending equally on either side of a central maximum will produce what type of curve?

a. Symmetrical.
b. Asymetrical.
c. Skewed.
d. U-shape.

20. (A11) A frequency curve having two maxima is called

a. bimodal.
b. trimodal.
c. multimodal.
d. hexamodal.

21. (A12) In the notation X_j, what does the subscript j represent?

a. Mode.
b. Average.
c. Index.
d. Sigma.

22. (A12) The Greek letter Σ is a symbol for

a. integration.
b. summation.
c. differentiation.
d. central tendency.

23. (A13) Find the arithmetic mean of the numbers 3, 9, 2, 6, 8, 14.

a. 3.
b. 5.
c. 7.
d. 9.

24. (A13) An airman completed exams on two blocks of instruction and one final. The grades are 80 and 90 for the two blocks and 85 on the final. With the final weighted three times the block exams, what is the weighted mean grade?

a. 80.
b. 85.
c. 90.
d. 95.

25. (A14) The median of a set of numbers is

a. their calculated average.
b. identical to the mode.
c. an average of position.
d. their arithmetic means.

26. (A14) What is the median for the set of numbers 1, 2, 2, 3, 4, 4, 5?

a. 1.
b. 2.
c. 3.
d. 4.

27. (A15) How many modes, if any, does the set 3, 4, 7, 9, 12, 16 contain?

a. Three modes.
b. Two modes.
c. One mode.
d. No mode.

28. (A15) Select the mode for the set of numbers 8, 3, 2, 4, 5, 4, 3, 4, 1, 2, 4, 6.

a. 2.
b. 4.
c. 6.
d. 8.

29. (A16) For symmetrical curves, the mean, median, and mode are

a. coincidental.
b. positively skewed.
c. negatively skewed.
d. moderately skewed.

30. (A17) What is the geometric mean of the set of numbers 4, 6, and 9?

a. 2.67.
b. 3.83.
c. 4.70.
d. 6.00.

31. (A17) In practice, the easiest way to compute the geometric mean is by

a. the product of numbers.
b. the Nth root.
c. logarithms.
d. the reciprocals of the numbers.

32. (A18) Using the formula $H = \frac{N}{\Sigma\left(\frac{1}{X}\right)}$, find the harmonic mean of the numbers 2, 3, 6.

a. 1.
b. 2.
c. 3.
d. 4.

33. (A19) In the symbols $H \leq G \leq \overline{X}$, stating the relationship between arithmetic, geometric, and harmonic means, the $\leq$ sign indicates

a. more than.
b. less than.
c. equal to.
d. identical.

34. (A19) In the symbols $H \leq G \leq \overline{X}$, the equality sign applies only if all numbers are

a. identical.
b. different.
c. negative.
d. positive.

35. (A20) The quadratic mean of a set of numbers is also known as the

a. harmonic mean.
b. arithmetic mean.
c. geometric mean.
d. root mean square.

36. (A20) The root mean square of the set of numbers 1, 3, 4, 5, 7 is

a. $\sqrt{20}$.
b. $\sqrt{15}$.
c. $\sqrt{10}$.
d. $\sqrt{5}$.

37. (A21) If a set of data is arranged in order of magnitude and the values are divided into four equal parts, these values are called

a. quantiles.
b. percentiles.
c. deciles.
d. quartiles.

38. (A22) The degree to which numerical data tend to spread out about a mean value is called

a. diffraction.
b. refraction.
c. dispersion.
d. reflection.

39. (A22) Which of the following is *not* a common measurement of variation?

a. Mean.
b. Range.
c. Standard deviation.
d. Mean deviation.

40. (A23) The difference between the largest and smallest number in a set is called the

a. mean deviation.
b. range.
c. standard deviation.
d. arithmetic mean.

41. **(A23) In the set of numbers 2, 3, 3, 5, 5, 8, 10, 12, the range is**

a. 3.
b. 5.
c. 8.
d. 10.

42. **(A24) A variation that measures the average distance covered by the spread of dispersed items from a central point is called**

a. standard deviation.
b. mean deviation.
c. quartile deviation.
d. measure of central tendency.

43. **(A24) When computing mean or average deviation, you should**

a. omit the signs.
b. maintain the signs.
c. not use absolute values.
d. square the negative numbers.

44. **(A25) The symbol Q is used to denote**

a. standard deviation.
b. geometric mean.
c. root mean.
d. quartile deviation.

45. (A26) Calculate σ by using the set of numbers 11, 13, 14, 15, 17, and applying this equation:

$$\sigma = \sqrt{\frac{\Sigma(X - \overline{X})^2}{N}}.$$

a. 1.0.
b. 1.5.
c. 2.0.
d. 2.5.

46. (A26) To find the standard deviation of a set of *grouped data*, which of the following equations should you use?

a. $\sigma = \sqrt{\frac{\Sigma(X - \overline{X})^2}{N}}$

b. $s = c.i.\sqrt{\frac{\Sigma fd^2 - \frac{(\Sigma fd)^2}{n}}{n - 1}}$

c. $s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n - 1}}{n - 1}}$

d. $s = \sqrt{\frac{\Sigma(X - \overline{X})^2}{n - 1}}$

47. (A27) The sum of the squares of the deviations from the arithmetic mean divided by the number of observations is the

a. standard deviation.
b. quartile deviation.
c. average.
d. variance.

48. **(A27) The square root of the variance is equal to the**

a. mean.
b. median.
c. standard deviation.
d. population average.

49. **(A28) When a curve departs from symmetry, we say that the curve is**
a. skewed.
b. bell-shaped.
c. Gaussian.
d. symmetrical.

50. (A28) When a distribution is skewed, what is the position of the mean in relation to the mode?

a. On the side with the longer tail.
b. On the side with the shorter tail.
c. In the center.
d. None of the above.

51. (A29) The shape of the curve displayed by a normal distribution is called

a. leptokurtic.
b. platykurtic.
c. mesokurtic.
d. standard.

52. (A29) The degree of peakedness of a distribution is called

a. platykurtic.
b. kurtosis.
c. mesokurtic.
d. leptokurtic.

53. (A30) If E_1 and E_2 are mutually exclusive events, then $Pr(E_1E_2) =$

a. 0.
b. 1.
c. 2.
d. 3.

54. (A30) E_1 is the event of drawing a queen from a deck of cards and E_2 is the probability of drawing a jack. What does $Pr(E_1)$ and $Pr(E_2)$ equal, respectively?

a. 2/52 and 2/52.
b. 1/52 and 1/52.
c. 1/26 and 1/26.
d. 1/13 and 1/13.

55. (A31) If the probability that A will be alive in 30 years is 0.6 and the probability that B will be alive in 30 years is 0.4, then the probability that they will both be alive in 30 years is

a. 0.08.
b. 0.16.
c. 0.24.
d. 0.32.

56. (A32) Because a variable (X) can assume certain values with given probabilities, it is often called

a. a continuous random variable.
b. a discrete random variable.
c. a dependent random variable.
d. an independent random variable.

57. (A32) The probability of getting a 5 when a pair of fair dice are rolled is 4/36. Therefore, if we roll the dice 900 times we would expect to get a 5

a. 100 times.
b. 75 times.
c. 50 times.
d. 25 times.

58. (A33) In factorial computation, 6! equals

a. 60.
b. 120.
c. 360.
d. 720.

59. (A33) How many ways can 5 different colored compensating filters be arranged in a row?

a. 15.
b. 30.
c. 60.
d. 120.

60. (A34) An array which permits making an infinite display of binomial coefficients is called Pascal's

a. theory.
b. display.
c. array.
d. triangle.

61. (A34) The binomial distribution is

a. a continuous probability distribution.
b. a discrete probability distribution.
c. used when events are intermittent.
d. applicable only to combinations.

62. (A35) The areas under a typical normal curve for Z units are expressed by

a. decimals.
b. percentages.
c. fractions.
d. logarithms.

63. (A35) When describing the area under a normal curve, the expression $Z = -3$ and $+3$ represents

a. 68 percent of the data.
b. 3 normal deviations on either side of the mean.
c. 3 standard deviations on either side of the mean.
d. 95 percent of the data.

64. (A36) A control chart that treats measured quality characteristics is a chart for

a. fraction defectives.
b. attributes.
c. variables.
d. number of defects.

65. (A36) A control chart that records the defect in a product is called a chart for

a. averages.
b. ranges.
c. attributes.
d. variables.

66. (A37) When dealing with samples, the standard deviation formula should be

a. $\sqrt{\frac{\Sigma(X-u)^2}{N}}$

b. $\sqrt{\frac{\Sigma(X-\overline{X})^2}{n-1}}$

c. $\sqrt{\frac{\Sigma X^2}{N}}$

d. $\sqrt{\frac{\Sigma fd^2 - \frac{(\Sigma fd)^2}{n}}{n-1}}$

67. (A38) When establishing control limits for ranges, and the sample size is 6 or less, the lower control limit will be

a. 0.18.
b. 0.14.
c. 0.08.
d. 0.00.

68. (A38) When a process starts out with a range that is rather high, it tells you that the difference between the maximum and minimum density readings is

a. large.
b. small.
c. low.
d. zero.

69. (A39) What two basic charts are needed for quality control?

a. $\overline{X}$ and σ.
b. $\overline{X}$ and R.
c. σ and $\overline{R}$.
d. s and $\overline{X}$.

70. (A40) The title in a statistical table should include all of the following *except* the

a. time period involved.
b. nature of the data presented.
c. customary classification for types of data.
d. locality in which the data were accumulated.

71. (A41) In addition to tests of significance, what other test is available to determine if any significant change in a process has occurred?

a. A t test.
b. A test of hypothesis.
c. A test of variance.
d. A z test.

72. (A41) What tests are made to discover if significant changes have occurred in a process?

a. Tests of significance.
b. Tests of variance.
c. Binomial distribution tests.
d. Harmonic mean tests.

73. (A42) In hypothesis testing, H_o is the symbol for

a. a type I error.
b. the open cell interval.
c. the alternative hypothesis.
d. the null hypothesis.

74. (A42) Any hypothesis which differs from a given hypothesis is called the

a. null hypothesis.
b. test hypothesis.
c. alternative hypothesis.
d. statistical hypothesis.

75. (A43) Known as errors of the first kind, type I errors are also called

a. alpha errors.
b. beta errors.
c. gamma errors.
d. delta errors.

76. (A43) In order to reduce type I and type II errors, what can you do to the sample size?

a. Increase.
b. Decrease.
c. Nothing.
d. Compromise.

77. (A44) If a .05 level of significance is chosen in designing a test of hypothesis, then there are how many chances in 100 that we would reject the hypothesis when it should be accepted?

a. 50.
b. 20.
c. 5.
d. 1.

78. (A44) A 5-percent level of significance tells us we are confident we have made the right decision what percentage of the time?

a. 95 percent.
b. 50 percent.
c. 25 percent.
d. 5 percent.

79. (A45) In the significance tests involving the normal distribution, if the actual sample statistic, s, lies outside the -1.96 and 1.96 area, what would your decision be?

a. Accept the null hypothesis.
b. Reject the null hypothesis.
c. Accept a hypothesis that should be rejected.
d. Reject a hypothesis that should be accepted.

80. (A45) In the significance tests involving the normal distribution, if the hypothesis is true, what is the percentage of confidence that the z score of the sample will be between -1.96 and 1.96?

a. 5 percent.
b. 50 percent.
c. 95 percent.
d. 100 percent.

81. (A46) To help you make a statistical decision about the efficiency of two different developing formulas, you

a. compile a statistical table.
b. make a frequency histogram.
c. run a test of significance.
d. calculate the standard deviation.

82. (A46) In testing the significance of a normal distribution when σ is known, the test statistic is

a. critical beyond 95 percent.
b. $X_{ij} = u + V_j + E_{ij}$.
c. the t score.
d. the z score.

83. (A47) In testing the significance of a sample vs population where σ is unknown, the test statistic is

a. $z = \dfrac{\overline{X} - \mu}{\sigma\sqrt{N}}$

b. $t = \dfrac{\overline{X} - \mu}{S/\sqrt{N}}$

c. $z = \dfrac{\overline{X} - \mu}{\sigma\sqrt{N}}$

d. an X^2 computation.

84. (A47) Having the calculated t larger than the book t indicates a significant difference and you would

a. substitute values.
b. select a 5-percent level.
c. accept the null hypothesis.
d. reject the null hypothesis.

85. (A48) Select the table in which you present all the essential analysis of variance calculations.

a. A statistical table.
b. A sum-over table.
c. An ANOVA table.
d. A data table.

86. (A48) If your calculated F is smaller than the book F, you can say, with what possibility of being wrong, that there is no significant difference between the variables?

a. 5 percent.
b. 50 percent.
c. 95 percent.
d. 100 percent.

87. (A49) Using the equation $Q_T = \Sigma X^2 - \dfrac{T^2}{N}$, what is the *first* thing you do to each individual X?

a. Sum.
b. Square.
c. Multiply.
d. Divide.

88. (A49) In the $Q_T = \Sigma X^2 - \dfrac{T^2}{N}$ equation, the $\dfrac{T^2}{N}$ is a

a. residual sum.
b. column total.
c. number of rows.
d. correction factor.

89. (A50) In a two-factor, nonreplicated analysis, we have

a. two null hypotheses.
b. two alternative hypotheses.
c. two null and two alternative hypotheses.
d. one null and one alternative hypotheses.

90. (A50) In the F test, if your calculated variance for columns is 1.04 and the book value is 3.67, you would

a. accept the null hypotheses.
b. reject the null hypotheses.
c. juggle the data.
d. calculate the difference.

91. (A51) When running an analysis of variance involving several variables, if the variation in some factors is due purely to chance, you should

a. eliminate these variables from the analysis.
b. pool the sums of the squares with the residual sums of the squares.
c. not consider their mean squares in the F test.
d. pool their sums of the squares with those of the other factors.

92. (A51) What is the guide a technician should use to help decide when *not* to pool?

a. If the degrees of freedom for the original error mean square are 6 or more.
b. If the variance for the sums of the squares to be pooled is not greater than 2.
c. If the degrees of freedom for the original error mean square falls between 2 and 3.
d. None of the above.

93. (A52) The repetition of a statistical test is called

a. replication.
b. duplication.
c. precision.
d. accuracy.

94. (A52) In a two-factor replicated analysis, the more data added to the analysis, the greater the

a. null hypothesis.
b. alternate hypothesis.
c. residual.
d. interaction.

95. (A53) What type of analysis has three variables to be considered?

a. Single-factor analysis of variance.
b. Two-factor analysis of variance.
c. Three-factor analysis of variance.
d. Single-factor and two-factor analysis of variance together.

96. (A53) In carrying out a three-factor analysis, you make three separate, two-factor tables giving the sums of the row and column values of paired factors. This is called

a. summing over.
b. sum of squares.
c. the correction factor.
d. interaction between factors.

97. (A54) An experiment in which the results obtained will answer the specific questions that prompted us to make the experiment is the definition for a

a. statistical experiment.
b. scientific experiment.
c. designed experiment.
d. detailed experiment.

98. (A54) Before designing an experiment, you should state in writing

a. your objective, a description of the experiment, and outline the method to be used to analyze the results.
b. a justification for conducting the experiment.
c. your estimate of the nature of the population, and the type and size of the sample to be drawn.
d. your decision whether to design a one-, two-, or three-factor test.

99. (A55) When designing statistical experiments, you must consider the ever-present experimental error. This error originates in the

a. random error and inherent bias.
b. irregularities in experimental design.
c. differences in skills of technicians.
d. nonuniformity of material and variability in technique.

100. (A55) In every statistical experiment, basic error can be reduced by

a. improving the material only.
b. improving the experimental technique only.
c. improving the material and/or improving the experimental technique.
d. none of the above.

101. (A56) The first step in preparing a designed experiment is to

a. prepare a report.
b. state the problem clearly.
c. design the experiment.
d. analyze the data.

102. (A56) What preparatory step do you take as an aid in designing statistical experiments?

a. Prepare a report.
b. Prepare a checklist.
c. Prepare a summary of all evidence.
d. Prepare tables and graphs.

103. (A57) Single-factor experiments are designed to make a comparison

a. between a film and developer.
b. between two batches of raw material.
c. among three materials.
d. among four products.

104. (A58) When you randomly select a set of machines and test the film on them, trying both films on each machine, you are setting up what type of design?

a. Randomized block.
b. Single-factor experiment.
c. The Latin square.
d. Graeco-Latin squares.

105. (A58) How does the randomized block test compare to a completely randomized test?

a. More efficient.
b. More accurate.
c. Less efficient.
d. Less sensitive.

106. (A59) When you have four factors to test, and each factor has the same number of variables; i.e., 4 materials, 4 operators, and 4 machines, you would design a

a. completely randomized test.
b. Graeco-Latin square test.
c. randomized block test.
d. Latin square test.

107. (A59) If you suspect any interaction between the factors being tested, do *not* use the

a. single-factor experiment design.
b. randomized block design.
c. Latin square design.
d. Graeco-Latin square design.

108. (A60) When you employ triple grouping to reduce errors, your experimental design may be called a

a. randomized block design.
b. Latin square design.
c. Graeco-Latin square design.
d. two-factor analysis of variance.

109. (A60) How does the Graeco-Latin square differ from Latin square when you run an analysis of variance?

a. You must also find the sum of the squares and the mean square for Graeco-Latin square.
b. You must also find the dividend of the squares and the root mean square for Graeco-Latin square.
c. You must also find the standard deviation of the squares and the mean square for Graeco-Latin square.
d. None of the above.

110. (A61) The construction of a frequency distribution is a basic tool for

a. accurate lab notebooks.
b. assembly of all data in one document.
c. changing continuous data into discrete data.
d. analysis of variability.

111. (A61) A frequency distribution curve has a higher than normal peak and a compressed horizontal range. Select the statement that describes this curve.

a. It is multimodal.
b. There is no evidence of kurtosis.
c. The process is especially accurate.
d. The curve is skewed.

112. (A62) When a test measures what it is intended to measure, it is said to be

a. valid.
b. reliable.
c. accurate.
d. precise.

113. (A62) What should be taken into consideration when you are selecting the method to determine validity?

a. Skill, time limitations, materials, products.
b. Skill, machines, materials, research data.
c. Knowledge, materials, facilities, products.
d. Skill, time limitations, facilities, research data.

114. (A63) If several pH readings of the same sample have been taken and the readings are all 7.0, you can say that the test is

a. valid.
b. invalid.
c. accurate.
d. reliable.

115. (A63) The degree of agreement between various runs of the same test or different tests is associated with two conditions. Select these conditions

a. Procedures must yield a consistent result and be designed to measure two different things.
b. Procedures must yield a dependable result and be designed to measure the same thing.
c. Procedures must yield the same result and be designed to measure a variety of things.
d. None of the above.

8.50

116. (A64) Standard deviation is defined as a method of expressing the

a. average density of ''sensi'' strips.
b. number of cases that are equal.
c. variation of data from the mean.
d. square root of D/max and D/min range.

117. (A64) If a curve is affected by kurtosis, one standard deviation would encompass what percentage of the data?

a. 34 percent.
b. 68 percent.
c. 95 percent.
d. 99 percent.

118. (A65) Another name for a Shewhart Chart is the

a. $\overline{X}$ chart.
b. $\overline{R}$ chart.
c. R chart.
d. Sigma chart.

119. (A65) A controlled process is operating almost on its mean, when suddenly three values drift toward the upper control limit (UCL). What will you do?

a. Stop the processing and find the cause.
b. Take immediate corrective measures.
c. Dump the solutions and replace them.
d. Monitor the process and see if a trend continues.

120. (A66) Short-term variability is a plot of several control points that are approaching a tolerance limit and then

a. return to their typical level.
b. consistently maintain this new value.
c. go completely out of control.
d. fluctuate from UCL to LCL.

121. (A67) It is possible to set the lower control limit on a range chart at

a. three.
b. two.
c. one.
d. zero.

122. (A67) If new acceptance limits are placed on an operation and the chemistry is modified to incorporate these limits, it is necessary to

a. continue using the original upper and lower control limits of the process.
b. construct a new frequency distribution and recalculate the standard deviation.
c. add the new computations of density, gamma, and pH to the old values for a representative average.
d. refine the new techniques until they are adequate before beginning acquisition of new data.

123. (A68) The replenishment requirements are determined by analyzing the solution after

a. corrective action.
b. decreasing KBr.
c. exhaustion.
d. adding water.

124. (A69) In establishing a replenisher formula, before any film is processed you

a. analyze developer for content.
b. determine proper development time for the fresh developer.
c. find the amount of KBr deficiency.
d. perform chemical quantitative analysis.

END OF EXERCISE

MAIL TO: ECI, GUNTER AFS AL 36118-5643

STUDENT REQUEST FOR ASSISTANCE

PRIVACY ACT STATEMENT

AUTHORITY: 10 USC 8012. PRINCIPAL PURPOSE: To provide student assistance as requested by individual students. ROUTINE USES: This form is shipped with ECI course package, and used by the student, as needed, to place an inquiry with ECI. DISCLOSURE: Voluntary. The information requested on this form is needed for expeditious handling of the student's inquiry. Failure to provide all information would result in slower action or inability to provide assistance to the student.

I. CORRECTED OR LATEST ENROLLMENT DATA

1. THIS REQUEST CONCERNS COURSE (1-6)
2. TODAY'S DATE
3. ENROLLMENT DATE
4. AUTOVON NUMBER
5. SOCIAL SECURITY NUMBER (7-15) ☐☐☐ - ☐☐ - ☐☐☐☐
6. GRADE/RANK
7. NAME (First initial, second initial, last name) (17) - (18) - (19-32)
8. ADDRESS
OJT ENROLLEES-Address of unit training office with zip code.
ALL OTHERS-Current mailing address with zip code.
(33-53)
(54-75)
9. NAME OF BASE OR INSTALLATION IF NOT SHOWN ABOVE
10. TEST CONTROL OFFICE ZIP CODE/SHRED (33-38)

II. REQUEST FOR MATERIALS, RECORDS, OR SERVICE

X	*Place an "X" through number in box to left of service requested.*
1	Request address change as indicated in Section I, Block 8.
2	Request Test Control Office change as indicated in Section I, Block 10.
3	Request name change/correction. *(Provide Old or Incorrect data here)*
4	Request Grade/Rank change/correction.
5	Correct SSAN. *(List incorrect SSAN here.)* *(Correct SSAN should be shown in Section I.)*
6	Extend course completion date. *(Justify in "Remarks")*
7	Request enrollment cancellation. *(Justify in "Remarks")*
8	Send VRE answer sheets for Vol(s): 1 2 3 4 5 6 7 8 9 10 Originals were: ☐ Not received ☐ Lost ☐ Misused
9	Send course materials. *(Specify in "Remarks")* ☐ Not received ☐ Lost ☐ Damaged
10	Course exam not yet received. Final VRE submitted for grading on __________ (date).
11	Results for VRE Vol(s) 1 2 3 4 5 6 7 8 9 10 not yet received. Answer sheet(s) submitted __________ (date).
12	Results for CE not yet received. Answer sheet submitted to ECI on __________ (date).
13	Previous inquiry (☐ ECI Fm 17, ☐ ltr, ☐ msg) sent to ECI on __________ (date).
14	Give instructional assistance as requested on reverse.
15	Other *(Explain fully in "Remarks")*

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	WC 39-42	

REMARKS *(Continue on reverse)*

OJT STUDENTS must have their OJT Administrator certify this record.

ALL OTHER STUDENTS may certify their own requests.

I certify that the information on this form is accurate and that this request cannot be answered at this station.

SIGNATURE

ECI FORM DEC 84 17 PREVIOUS EDITION WILL BE USED.

BEST COPY AVAILABLE

REQUEST FOR INSTRUCTOR ASSISTANCE

NOTE: Questions or comments relating to the accuracy or currency of subject matter should be forwarded directly to preparing agency. For an immediate response to these questions, call or write the course author directly, using the AUTOVON number or address in the preface of each volume. All other inquiries concerning the course should be forwarded to ECI.

VRE ITEM QUESTIONED:

COURSE NO ____________

VOLUME NO ____________

VRE FORM NO ____________

VRE ITEM NO ____________

ANSWER YOU CHOSE ____________ (Letter)

HAS VRE ANSWER SHEET BEEN SUBMITTED FOR GRADING?

☐ YES ☐ NO

REFERENCE

(Textual reference for the answer I chose can be found as shown below.)

IN VOLUME NO ____________

ON PAGE NO ____________

IN ☐ LEFT ☐ RIGHT COLUMN

LINES ________ THROUGH ________

MY QUESTION IS:

REMARKS

ADDITIONAL FORMS 17 available from trainers, OJT and Education Offices, and ECI. Course workbooks have a Form 17 printed on the last page.

ECI FORM 17, DEC 86 (Reverse)